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ABSTRACT

Presented are the teacher's guide and student materials for one of a series of self-instructional, computer-based learning modules for an introductory, undergraduate chemistry course. The student manual for this unit on chemical equilibrium calculations includes objectives, prerequisites, a discussion of the equilibrium constant (K), and ten problem sets. Included in the teacher's guide are implementation instructions, problem solutions, software, a sample run of the program in BASIC, and 20 unit tests on equilibrium calculations. (BT)

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CHEMICAL EQUILIBRIUM

UNIT 3. CHEMICAL EQUILIBRIUM CALCULATIONS

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A COMPUTER-ENRICHED MODULE
FOR INTRODUCTORY CHEMISTRY

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

$$K = \frac{(NH_3)^2}{(N_2)(H_2)^3}$$

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OBJECTIVES

When you finish this unit you will be able to

1. find the equilibrium constant for a reaction given the equilibrium concentrations of all the species.
2. find the equilibrium constant for a reaction given the initial amounts of all species and the equilibrium amount of any one species.
3. calculate the extent of a reaction from the equilibrium constant.
4. predict the equilibrium state from the equilibrium constant.
5. predict the direction of a reaction from the equilibrium constant and initial conditions.
6. calculate the new equilibrium state of a system upon changing any one of the following conditions (amounts of any reactant or product, pressure, volume).

PREREQUISITES

Before you start this unit you should be able to

1. define the equilibrium constant of a reacting system in terms of concentrations.
2. solve a linear equation in one unknown, and a quadratic equation in one unknown.
3. determine relationships between amounts of reactants and products (stoichiometry).

INTRODUCTION

In the previous units we have discovered that there is a unique constant at a given temperature for a given reacting system. We have seen that this unique constant relates the equilibrium concentrations of reactants and products to each other so that for a reaction $aA + bB = cC + dD$, the value of

$$\frac{[C]^c[D]^d}{[A]^a[B]^b}$$

at equilibrium is constant regardless of the initial conditions such as amounts of reactants or products initially present, volume, or pressure. We have also seen qualitatively how a system in equilibrium reacts when a change in conditions is imposed upon it: the system always reacts in such a way as to relieve the effect of the imposed change within the constraint of maintaining the equilibrium constant the same. A new equilibrium state is established and the equilibrium constant is still the same as before so long as the temperature remains the same.

Here we explore further the areas covered previously, but with a quantitative approach. You will

a. find the equilibrium constant for a reaction.
b. use the equilibrium constant to predict the extent of a reaction, the direction of a reaction and the new equilibrium state to which a system shifts when a change in conditions such as amount of a reactant or product, volume, or pressure is imposed upon it.

For this unit you will be using the programs EQUIL, EQCALC, and EQUIZ. EQUIZ will provide additional problems and their answers for the purposes of review and practice.

DISCUSSION

A. Finding K for a Reaction:

For any chemical system, we can find the constant of equilibrium for the system experimentally by allowing the system to approach equilibrium and then measuring the concentrations of all the substances in the system when equilibrium is reached.

Example 1. Consider the equilibrium

$$N_2(g) + 3\ H_2(g) = 2\ NH_3(g)\ .$$

At 220°C a certain equilibrium mixture in a 3.0 liter container consists of 0.60 mole of NH_3, 0.30 mole of H_2 and 0.45 mole of N_2. Find the equilibrium constant for the reaction.

Solution: The equilibrium concentrations are:

$$[NH_3] = \frac{0.60\ \text{mole}}{3.0\ \text{liter}} = 0.20\ \text{moles/liter}$$

$$[H_2] = \frac{0.30\ \text{mole}}{3.0\ \text{liter}} = 0.10\ \text{moles/liter}$$

$$[N_2] = \frac{0.45\ \text{mole}}{3.0\ \text{liter}} = 0.15\ \text{moles/liter}$$

The equilibrium constant for this reaction is:

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(0.20)^2}{(0.15)(0.10)^3} = 2.67 \times 10^2$$

Find the equilibrium constant for each of the following systems:

Problem 2. At equilibrium, the concentrations of the gases in the reaction

$$CO_2 + CF_4 \rightleftharpoons 2\ COF_2$$

are:

$[CO_2] = 6.49 \times 10^{-2}$ M
$[CF_4] = 6.49 \times 10^{-2}$ M
$[COF_2] = 1.03 \times 10^{-2}$ M

Calculate the equilibrium constant.

Problem 3. At equilibrium, the concentrations of the gases in the reaction

$$SO_2 + Cl_2 \rightleftharpoons SO_2Cl_2$$

are:

$[SO_2]$ = 3.53×10^{-3} M

$[Cl_2]$ = 3.53×10^{-1} M

$[SO_2Cl_2]$ = 1.25×10^{-4} M

Calculate the equilibrium constant.

It is not really necessary to measure the concentrations of all the species in the system at equilibrium. If we measure the amounts of starting materials placed in the reaction vessel of given volume it is sufficient to know the amount present at equilibrium of any one of the reactants or products in order to find the equilibrium constant for the reaction. This is so because of the inter-relationship between the amounts of reactants which react and the amounts of products formed (which we have already discovered in the module on stoichiometry).

Example 4. One mole of N_2O_4 is placed in a 5.0 liter container at 100°C. Part of it dissociates to form NO_2. At equilibrium, 1.00 mole of NO_2 is present. Calculate K for the reaction $N_2O_4(g) = 2\ NO_2(g)$.

Solution:

$N_2O_4(g)$	=	$2\ NO_2(g)$	
1.00		0	initial number of moles
?		1.00	moles at equilibrium

The number of moles of N_2O_4 which was used up in forming 1.00 mole of NO_2 is

$$1.00 \text{ moles } NO_2 \left(\frac{1 \text{ mole } N_2O_4}{2 \text{ moles } NO_2} \right) = 0.50 \text{ moles } N_2O_4 .$$

If 0.50 moles of N_2O_4 was used up in forming NO_2, then the moles of N_2O_4 left out of a starting amount of 1.00 mole of N_2O_4 is

1.00	-	0.50	=	0.50
moles of N_2O_4 at start		moles of N_2O_4 used up		moles of N_2O_4 left

Thus, the equilibrium number of moles present are:

N_2O_4: 0.50 moles NO_2: 1.00 moles

The equilibrium concentrations are:

$[N_2O_4]$ = 0.50 moles/5.0 liters = 0.10 moles/liter

$[NO_2]$ = 1.00 moles/5.0 liters = 0.20 moles/liter

Therefore, the equilibrium constant for the reaction

$$N_2O_4(g) = 2\ NO_2(g)$$

is

$$K = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(0.20)^2}{(0.10)} = 0.40 .$$

Example 5. For the reaction

$$2\ NO(g) + O_2(g) = 2\ NO_2(g)$$

it is found that when 0.40 mole of NO and 0.60 mole of O_2 are added to a 3.0 liter container at 620°C, 0.16 mole of NO_2 is formed at equilibrium. Calculate K for the reaction at 620°C.

Solution: If 0.16 mole of NO_2 is formed, then this must have come from

$$0.16 \text{ mole } NO_2 \left(\frac{2 \text{ moles NO}}{2 \text{ moles } NO_2} \right) = 0.16 \text{ mole NO}$$

and

$$0.16 \text{ mole } NO_2 \left(\frac{1 \text{ mole } O_2}{2 \text{ moles } NO_2} \right) = 0.080 \text{ mole } O_2.$$ The appearance (+) of 0.16 moles of NO_2 is accompanied by the disappearance (-) of 0.08 moles of O_2 and 0.16 moles of NO.

	$2\ NO$	+ O_2	= $2\ NO_2$
initial no. of moles from data	0.40	0.60	0
change in moles	-0.16	-0.08	+0.16
no. of moles at equilibrium	0.40 - 0.16 = 0.24	0.60 - 0.08 = 0.52	0 + 0.16 = 0.16
equilibrium concentration	$\frac{0.24 \text{ moles}}{3.0 \text{ liters}}$ = 0.08	$\frac{0.52 \text{ moles}}{3.0 \text{ liters}}$ = 0.17	$\frac{0.16 \text{ moles}}{3.0 \text{ liters}}$ = 0.053

Therefore the equilibrium constant for the reaction

$$2\ NO(g) + O_2(g) = 2\ NO_2(g)$$

is

$$K = \frac{[NO_2]^2}{[NO]^2[O_2]} = \frac{(0.053)^2}{(0.08)^2(0.17)} = 2.58 .$$

Example 6. 1.24 moles of H_2 and 5.08 moles of N_2 were introduced into an empty 10.0 liter container at 400°C. When equilibrium was attained, 0.159 mole of NH_3 was formed. Fill the table and calculate K for

$$N_2(g) + 3\ H_2(g) = 2\ NH_3(g)$$

initial no. of moles from data			
changes in moles from the chemical equation			
no. of moles at equilibrium			
equilibrium concentrations	$\frac{5.0 \text{ moles}}{10.0 \text{ liters}}$	$\frac{1.00 \text{ moles}}{10.0 \text{ liters}}$	$\frac{0.159 \text{ moles}}{10.0 \text{ liters}}$

The equilibrium constant for the reaction

$$N_2(g) + 3\ H_2(g) = 2\ NH_3(g)$$

is

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(0.159)^2}{(0.50)(0.10)^3} = 0.506 \text{ (at 400°C)} .$$

Example 7. At 240°C 5.0 moles of PCl_5 placed in a 20.0 liter flask is found to be 35% dissociated into PCl_3 and Cl_2. What is the equilibrium constant for the reaction

$$PCl_3(g) + Cl_2(g) = PCl_5(g) \ ?$$

Solution: If PCl_5 is 35% dissociated, then 0.35(5.0) = 1.75 moles of PCl_5 will be converted to PCl_3 and Cl_2.

	PCl_3 +	Cl_2 =	PCl_5
initial number of moles	0	0	5.0
changes in moles from chemical equation	1.75	1.75	-1.75
moles at equilibrium	0 + 1.75	0 + 1.75	5.0 - 1.75
equilibrium concentrations	$\frac{1.75 \text{ moles}}{20.0 \text{ liters}}$ = 0.0875	$\frac{1.75 \text{ moles}}{20.0 \text{ liters}}$ = 0.0875	$\frac{3.25 \text{ moles}}{20.0 \text{ liters}}$ = 0.1625

Thus, the equilibrium constant for the reaction

$$PCl_3(g) + Cl_2(g) = PCl_5(g)$$

is

$$K = \frac{[PCl_5]}{[PCl_3][Cl_2]} = \frac{(0.1625)}{(0.0875)(0.0875)} = 21.22 \ .$$

Example 8. Consider the reaction

$$CaCO_3(s) = CaO(s) + CO_2(g)$$

at 740°C. Starting with 0.100 mole of $CaCO_3$ in a 10.0 liter container, calculate the equilibrium constant for this reaction if it is found that 0.060 moles of CO_2 are present at equilibrium.

Solution: Pure solids or pure liquids have concentrations which remain constant and are therefore not included in the expression for the constant of equilibrium for the system. Thus for the reaction

$$CaCO_3(s) = CaO(s) + CO_2(g)$$

the constant of equilibrium is

$$K = [CO_2] \ .$$

Since the data gives the number of moles of CO_2 present at equilibrium, then we can immediately find K:

$$[CO_2] = \frac{0.060 \text{ moles } CO_2}{10.0 \text{ liters}}$$

$$K = [CO_2] = 0.006$$

Note that the number of moles of $CaCO_3$ or CaO do not enter into consideration at all. The same equilibrium concentration of CO_2 will be

reached even if we had started with 0.5 mole $CaCO_3$ or 1.0 mole of $CaCO_3$ or any number of moles of $CaCO_3$ provided that there is some $CaCO_3$ left at equilibrium with the CO_2 gas.

Find the equilibrium constant in each of the following systems:

Problem 9. Into an evacuated 10-liter vessel are introduced 2.0 moles of NH_3 and 1.0 mole of O_2. When equilibrium was established

$$4\ NH_3(g) + 3\ O_2(g) = 2\ N_2(g) + 6\ H_2O(g)$$

0.5 mole of N_2 was found in the equilibrium mixture. Calculate the equilibrium constant for this reaction.

Problem 10. When 3.0 moles of NO gas and 5.0 moles of Br_2 gas are placed in a 5.0 liter container, it is found that only 0.2 mole of NO gas remains in the equilibrium mixture. What is the constant of equilibrium for this reaction?

$$2\ NO(g) + Br_2(g) = 2\ NOBr(g)$$

Problem 11. CO_2 gas reacts with H_2 gas producing CO and water vapor. One mole each of the four gases in a 2.0 liter flask at 700°C reaches an equilibrium condition in which the water vapor present is only 0.885 mole. Calculate the equilibrium constant for the reaction

$$CO_2(g) + H_2(g) = CO(g) + H_2O(g)$$

Problem 12. A mixture containing 0.225 mole of HCl(g) and 0.10 mole of $O_2(g)$ is allowed to come to equilibrium at 480°C in a 3.0 liter reaction chamber. At equilibrium the concentration of $Cl_2(g)$ is 0.030 mole/liter. What is the value of K at 480°C?

$$4\ HCl(g) + O_2(g) = 2\ Cl_2(g) + 2\ H_2O(g)$$

Problem 13. At 950°K and a concentration of 0.125 mole/liter SO_3 gas is 60% dissociated. What is the equilibrium constant for

$$2\ SO_3(g) = 2\ SO_2(g) + O_2(g)\ ?$$

Problem 14. Pure iron can be produced by the reduction of the oxide with H_2:

$$Fe_2O_3(s) + 3\ H_2(g) = 2\ Fe(s) + 3\ H_2O(g)\ .$$

At 340°C 500 grams of Fe_2O_3 is placed in contact with 4.0 moles of H_2 gas in a 2.0 liter reaction chamber. When equilibrium is reached, it is found that 42.5 g of Fe(s) has been obtained. What is the equilibrium constant for the reaction?

B. Of What Value is the Equilibrium Constant?

Once the equilibrium constant has been determined for a reaction at a given temperature, it can be used by anyone who wishes to carry out the reaction in the laboratory or to make predictions about the reaction at that temperature. We have seen in Unit 1 that qualitatively, the magnitude of K implies something about how far the reaction goes forward, or given initial conditions, which direction a chemical system will go (forward or backward) in its approach to equilibrium. In this unit we will see that the equilibrium constant can be used to decide:

1. The extent to which a reaction will occur.
2. The direction in which a chemical reaction will move to reach equilibrium.
3. The effect that a change in conditions will have on a chemical system at equilibrium.

Let us now consider each of these applications of the constant of equilibrium.

Use of K to Determine the Extent to Which a Reaction Will Occur

At this point, use program EQUIL.

In EQUIL you have seen how you can find the extent to which a chemical reaction will occur, from the equilibrium constant. This trial and error method will always get you to the correct answer no matter how complicated the reaction may be. To see how well it works for your choice of reaction (something like $4\ HCl + O_2 = 2\ H_2O + 2\ Cl_2$ or worse) starting with your choice of any number of moles of reactants, use program EQCALC.

Since the number of moles of products formed and the number of moles of any reactant used up in a reaction are all beautifully and concisely embodied by the chemical equation, then the amount of any one and only one of the reactants used up, or products formed needs to be found! All the other amounts are nicely related to it by the chemical equation. Thus, there is only one unknown quantity and there is one known constant, the constant of equilibrium. Let's see how we can get one from the other:

Example 15. The equilibrium constant for the reaction

$$CO(g) + Cl_2(g) = COCl_2(g)$$

is $K = 3.83 \times 10^9$ at 100°C. Find the degree of dissociation of 5.0 moles of $COCl_2$ in a 20.0 liter container.

Solution: Here we are given the equilibrium constant and we wish to determine the extent to which $COCl_2$ is dissociated into $CO + Cl_2$. In other words, how far to the left does the reaction go?

Let y = number of moles of CO at equilibrium. The number of moles of Cl_2 at equilibrium is then

$$y \text{ moles } CO\left(\frac{1 \text{ mole } Cl_2}{1 \text{ mole } CO}\right) = y \text{ moles } Cl_2$$

and the number of moles of $COCl_2$ which disappeared when y moles of CO is formed, is

$$y \text{ moles of } CO\left(\frac{1 \text{ mole } COCl_2}{1 \text{ mole } CO}\right) = y \text{ moles } COCl_2.$$

	CO	+ Cl_2	= $COCl_2$
initial no. of moles	0	0	5.0
change in moles, from the chemical equation	+y	+y	-y
equilibrium no. of moles	0 + y	0 + y	5.0 - y
equilibrium concentrations	$\frac{y}{20.0}$	$\frac{y}{20.0}$	$\frac{5.0 - y}{20.0}$

What is the maximum value that y can have? [redacted]

We can now use K for this reaction to find out what y is:

$$K = 3.83 \times 10^{9} = \frac{[COCl_2]}{[CO][Cl_2]} = \frac{\left(\frac{5.0 - y}{20.0}\right)}{\left(\frac{y}{20.0}\right)\left(\frac{y}{20.0}\right)}$$

$$3.83 \times 10^{9} = 20.0(5.0 - y)/y^2$$

Since K is very large then we conclude that only very little $COCl_2$ is dissociated into CO and Cl_2, that is, y is very small compared to 5.0. Therefore, we may use the approximation that $5.0 - y = 5.0$; so that $3.83 \times 10^{9} = 20.0(5.0)/y^2$.

$$y^2 = 20.0(5.0)/(3.83 \times 10^{9}) = 2.61 \times 10^{-8}$$
$$y = 1.61 \times 10^{-4} .$$

At this point we should check to see whether we were justified in approximating 5.0 - y by 5.0. We see that indeed we were, since $(5.0 - 1.61 \times 10^{-4})$ or 4.999839 is very close to 5.0. The degree of dissociation is

$$\frac{\text{the amount dissociated}}{\text{the original amount}} = y/5.0 = 3.23 \times 10^{-5}.$$

Thus, the degree of dissociation of 5.0 moles of $COCl_2$ in a 20.0 liter container is 3.23×10^{-5}, a very small number. The percent dissociation is $100 \times 3.23 \times 10^{-5} = 3.23 \times 10^{-3}$%. At 100°C, therefore, nearly all of $COCl_2$ remains as such and only a minute amount undergoes the backward dissociation reaction.

Example 16. At 520°C, the constant of equilibrium for the reaction

$$2\ HI(g) = H_2(g) + I_2(g)$$

is 0.0156. If 2.00 moles of HI are introduced into an evacuated 10.0 liter container, what fraction of HI will decompose? What are the resulting concentrations of H_2, I_2, and HI?

Solution: Let y = number of moles of H_2 which appear. The number of moles of I_2 which appear, according to the chemical equation are:

$$y \text{ moles } H_2\left(\frac{1 \text{ mole of } I_2}{1 \text{ mole } H_2}\right) = y \text{ moles } I_2$$

and the number of moles of HI which disappeared in forming y moles of H_2 is, according to the equation,

$$y \text{ moles of } H_2\left(\frac{2 \text{ moles HI}}{1 \text{ mole } H_2}\right) = 2\ y \text{ moles of HI} .$$

	2 HI	= H_2	+ I_2
initial moles	2.00	0	0
change in moles	-2y	y	y
equilibrium moles	2.00 - 2y	0 + y	0 + y
equilibrium concentration	$\frac{2.00 - 2y}{10.0}$	$\frac{y}{10.0}$	$\frac{y}{10.0}$

What is the maximum value that y can have?

From the equilibrium constant which is 0.0156, we can find y:

$$K = 0.0156 = \frac{[H_2][I_2]}{[HI]^2} = \frac{\left(\frac{y}{10.0}\right)\left(\frac{y}{10.0}\right)}{\left(\frac{2.00 - 2y}{10.0}\right)^2}$$

$$0.0156 = \frac{y^2}{(2.00 - 2y)^2}$$

Taking the square root of both sides,

$$\sqrt{0.0156} = 0.125 = y/(2.00 - 2y)$$

$$y = 0.125(2.00 - 2y) = 0.25 - 0.25y$$

$$1.25y = 0.25$$

$$y = 0.20 .$$

The fraction of HI which decomposed is

$$\frac{\text{amount which decomposed}}{\text{initial amount}} = \frac{2y}{2.00} = \frac{0.40}{2.00} = 0.20 .$$

In other words HI is 20% decomposed or dissociated at 520°C. The equilibrium concentrations are

$$[HI] = \frac{2.00 - 2y}{10.0} = \frac{1.60}{10.0} = 0.16 \text{ moles/liter}$$

$$[H_2] = \frac{y}{10.0} = 0.020 \text{ moles/liter}$$

$$[I_2] = \frac{y}{10.0} = 0.020 \text{ moles/liter} .$$

We see that K is useful in determining the extent to which a reaction will occur. This is very important in commercial preparation of chemicals. Obviously $COCl_2$ at 100°C is a very, very poor source of CO or Cl_2 because, as we have seen, of 5.0 moles in a 20.0 liter container, only 1.61×10^{-4} moles become converted to CO and Cl_2. By the same token, provided the reaction $CO + Cl_2 = COCl_2$ were sufficiently fast, this method would be a good commercial one for the preparation of phosgene ($COCl_2$). If we start with 5.0 moles of CO and 5.0 moles of Cl_2, we get almost complete conversion to 5.0 moles of $COCl_2$, that is, all but a minute fraction (1.61×10^{-4} moles). This amounts to 99.997% conversion of CO and Cl_2 to $COCl_2$. This is one of those cases which we sometimes refer to as a reaction which goes nearly to completion. On the other hand, the reaction $2\ HI = H_2 + I_2$ only goes to 20% completion at 520°C.

Use the equilibrium constant to find the extent of reaction in each of the following systems:

Problem 17. For the equilibrium: $Br_2 + Cl_2 \rightleftharpoons 2\ BrCl$
the equilibrium constant is: $K = 8.170 \times 10^{+2}$ at 573K. Find the degree of dissociation of 0.397 moles of BrCl in a 10-liter flask.

Problem 18. For the equilibrium: $C_2H_4 + H_2 \rightleftharpoons C_2H_6$ the equilibrium constant is: $K = 1.480 \times 10^3$ at 900K. 2.875 mole each of C_2H_4 and H_2 gases are placed in a 2.65 liter flask at 627°C. Find the ratio of the total pressure at equilibrium to the original total pressure.

Problem 19. If 2.905 mole of N_2 gas and 3.728 mole of O_2 gas are placed in a 5.30 liter tank at 2000°C, how many moles of NO will be present at equilibrium? For the equilibrium: $N_2 + O_2 \rightleftharpoons 2\ NO$ the equilibrium constant is: $K = 1.000 \times 10^{-1}$ at 2273K.

Problem 20. 3.070 moles of BrCl is placed in a 7.60 liter flask at 300°C. When the contents have come to equilibrium, what will be the concentrations of all the gases? For the equilibrium: $Br_2 + Cl_2 \rightleftharpoons 2\ BrCl$ the equilibrium constant is: $K = 8.170 \times 10^2$ at 573K.

Problem 21. When the system $CO + Cl_2 \rightleftharpoons COCl_2$ is at equilibrium, the concentrations are:

$[CO] = 6.42 \times 10^{-6}$ M

$[Cl_2] = 6.42 \times 10^{-6}$ M

$[COCl_2] = 1.58 \times 10^{-1}$ M

What is the degree of dissociation of $COCl_2$?

Produce additional exercises for you own use by running program EQUIZ. You may print any number of such exercises for your own use.

Those of you who are less adventurous may skip the following and go on to the use of K to predict the direction in which a chemical system will go.

How does the degree of dissociation change with concentration? That is the question.

You have seen in Example 16 that at 520°C the reaction

$$2\ HI(g) = H_2(g) + I_2(g) \qquad K = 0.0156$$

starting with 2 moles of HI in a 10.0 liter container reached 20% dissociation. Discover whether the percent dissociation of HI changes with concentration by considering, in turn, 5 moles of HI and then 10 moles of HI in 20 liters. Compare results with Example 16. How about the $SO_2Cl_2(g) = SO_2(g) + Cl_2(g)$ ($K = 1 \times 10^{-3}$) system? Discover whether the percent dissociation of SO_2Cl_2 changes with concentration, by considering any three different initial concentrations of SO_2Cl_2. (For example, compare the degree of dissociation in 1 mole, 2 moles, 5 moles of SO_2Cl_2 in 1.0 liter.) Can you now answer the question?

Use of K to Predict the Direction in Which a Chemical System Will Go

Example 22. Suppose one mole each of HI, I_2 and H_2 are placed in a 1.00 liter container at 520°C. Will more HI be produced, or will more $H_2 + I_2$ be produced? In other words, which direction will the chemical system $2\ HI = I_2 + H_2$ go (backward or forward)? What is the equilibrium state of the system?

Solution: In order to predict the direction in which the reaction

$$2\ HI(g) = I_2(g) + H_2(g) \qquad K = 0.0156$$

will go, let us see the value of the reaction quotient Q for the initial conditions give. Initially all of $[I_2]$, $[H_2]$, and [HI] are equal to 1.0 moles/1.0 liter or 1.0 moles/liter.

$$Q = \frac{[I_2][H_2]}{[HI]^2} = \frac{(1.0)(1.0)}{(1.0)^2} = 1.0$$

But the equilibrium constant is 0.0156. Thus, the system has to go from Q = 1.0 toward 0.0156. This can only be done by the system decreasing the numerator of Q (that is, by using up $H_2 + I_2$) at the same time as it is increasing the denominator of Q (that is, by increasing the amount of HI). Thus, the system is predicted to go in the backward direction

$$2\ HI \longleftarrow H_2 + I_2$$

in its approach to equilibrium. The equilibrium state can be determined as follows:

Let y = moles of H_2 used up.

	$2\ HI$	= H_2	+ I_2
initial moles	1.00	1.00	1.00
change in moles, from chemical equation	+2y	-y	-y
equil. moles	1.00 + 2y	1.00 - y	1.00 - y
equilibrium concentration	$\frac{1.00 + 2y}{1.00}$	$\frac{1.00 - y}{1.00}$	$\frac{1.00 - y}{1.00}$

What is the maximum value that y can have?

$$K = 0.0156 = \frac{\left(\frac{1.00 - y}{1.00}\right)\left(\frac{1.00 - y}{1.00}\right)}{\left(\frac{1.00 + 2y}{1.00}\right)^2} = \frac{(1.00 - y)^2}{(1.00 + 2y)^2}$$

Taking the square root of both sides,

$$\sqrt{0.0156} = 0.125 = \frac{1.00 - y}{1.00 + 2y}$$

$$y = 0.70 .$$

The equilibrium state is given by:

$$[HI] = \frac{1.00 + 2y}{1.00} = \frac{1.00 + 1.40}{1.00} = 2.40 \text{ moles/liter}$$

$$[H_2] = \frac{1.00 - y}{1.00} = 0.30 \text{ moles/liter}$$

$$[I_2] = \frac{1.00 - y}{1.00} = 0.30 \text{ moles/liter} .$$

We see that we can use the constant of equilibrium to predict the direction in which a reaction will go.

Is there an alternative way of finding the equilibrium state of the system discussed above? We have seen in Unit 1 that it is immaterial whether we start from all reactants, or all products, or some combination of reactants and products, the constant of equilibrium for a chemical reaction is the same for a given temperature. Thus, we would still reach the same equilibrium state for the above system if we had started with all of the moles being in the form of HI. Let us find the equilibrium state with this approach.

Once again, we place in a 1.00 liter container at 520°C one mole each of HI, I_2, and H_2. Had all of the I_2 and H_2 started out as HI, they would have been, according to the chemical equation, 1.0 mole $H_2\left(\frac{2 \text{ moles HI}}{1 \text{ mole } H_2}\right)$ = 2.0 moles HI. Similarly, 1.0 mole $I_2\left(\frac{2 \text{ moles HI}}{1 \text{ mole } I_2}\right)$ = 2.0 moles HI. In other words there is enough, and just enough H_2 and I_2 to have come from 2.0 moles HI. Thus, we see that starting out with initial moles of HI, H_2 and I_2 of 1.0, 1.0, 1.0 would be the same as starting out with 3.0, 0, 0 moles respectively. Of course, if one of H_2 or I_2 were in stoichiometric excess, one would have to use the limiting reagent (see stoichiometry module) as the basis for finding the number of moles of HI.

	2 HI	= H_2	+ I_2
initial moles	1.0	1.0	1.0
instead start out with	3.0	0.	0.
Let y = moles of H_2 at equilibrium.			
change in moles	-2y	y	y
equilibrium concentration	$\frac{3.0 - 2y}{1.0}$	$\frac{0 + y}{1.0}$	$\frac{0 + y}{1.0}$

What is the maximum value that y can have?

$$K = 0.0156 = \frac{[H_2][I_2]}{[HI]} = \frac{y^2}{(3.0 - 2y)^2}$$

Taking the square root of both sides,

$$1.25 = \frac{y}{3.0 - 2y}$$

$$y = 0.30 .$$

The equilibrium state is therefore:

$$[HI] = \frac{3.0 - 2y}{1.0} = \frac{3.0 - 0.60}{1.0} = 2.40 \text{ moles/liter}$$

$$[H_2] = \frac{y}{1.0} = 0.30 \text{ moles/liter}$$

$$[I_2] = \frac{y}{1.0} = 0.30 \text{ moles/liter} .$$

Note that this is exactly the same set of concentrations, the same equilibrium state that we found by the first method. Another alternative way of doing the problem is to place all the initial moles in the form of H_2 + I_2. If we convert according to the chemical equation all of 1.0 mole of HI into moles of H_2 and I_2, we will get

$$1.0 \text{ mole of HI}\left(\frac{1 \text{ mole } H_2}{2 \text{ moles HI}}\right) = 0.5 \text{ moles of } H_2$$

$$1.0 \text{ mole of HI}\left(\frac{1 \text{ mole } I_2}{2 \text{ moles HI}}\right) = 0.5 \text{ moles of } I_2$$

Instead of starting with 1.0 mole of each, we could start with 0 moles HI, 1.5 moles H_2 and 1.5 moles I_2. We should still arrive at the same equilibrium state. Let's see:

	$2\,HI(g)$ =	$H_2(g)$ +	$I_2(g)$
initial moles	1.0	1.0	1.0
instead start out with	0	1.5	1.5
Let y = moles of H_2 which disappear (-) at equilibrium.			
change in moles	+2y	-y	-y
equilibrium concentration	$\frac{0 + 2y}{1.0}$	$\frac{1.5 - y}{1.0}$	$\frac{1.5 - y}{1.0}$

What is the maximum value that y can have? [ ]

$$K = 0.0156 = \frac{[H_2][I_2]}{[HI]} = \frac{\left(\frac{1.5 - y}{1.0}\right)\left(\frac{1.5 - y}{1.0}\right)}{\left(\frac{2y}{1.0}\right)^2}$$

Taking the square root of both sides,

$$\sqrt{0.0156} = 0.125 = \frac{1.5 - y}{2y}$$

$$y = 1.2 \ .$$

The equilibrium state is therefore:

$$[HI] = \frac{0 + 2y}{1.0} = \frac{2(1.2)}{1.0} = 2.4 \text{ moles/liter}$$

$$[H_2] = \frac{1.5 - y}{1.0} = \frac{1.5 - 1.2}{1.0} = 0.30 \text{ moles/liter}$$

$$[I_2] = \frac{1.5 - y}{1.0} = 0.30 \text{ moles/liter} \ .$$

Again this is the exact same equilibrium state as we arrived at in the first two approaches we have used. If in fact we initially start with 2.40 moles HI, 0.30 moles of H_2 and 0.30 moles of I_2, we would have reached the same equilibrium state too.

You have seen that you can use any of 3 approaches to equilibrium and get to the same equilibrium state. It is advantageous to start from a point not too far from equilibrium so that the unknown change in concentrations is small. For example, if $K > 100$ it would be better to place as many moles as possible in the form of products since the equilibrium state is going to be closer to products. On the other hand, if $K < 0.01$ then it would be better to place all of the moles in the form of reactants. In between 0.01 and 100 any one of the 3 approaches can be used. Handle the latter cases with care since your unknown x or y will probably not be small compared to initial concentrations.

Problem 23. For the equilibrium: $I_2 + Cl_2 \rightleftharpoons 2\ ICl$ the equilibrium constant is: $K = 2.000 \times 10^5$ at 298K. 3.930 moles of I_2, 0.702 moles of Cl_2 and 4.758 moles of ICl gas are introduced into an evacuated 2.40 liter flask at 25°C. Find the equilibrium concentrations of all the gases.

Problem 24. For the equilibrium: $H_2 + I_2 \rightleftharpoons 2\ HI$ the equilibrium constant is: $K = 6.250 \times 10^2$ at 523K. 0.535 moles of H_2, 0.117 moles of I_2 and 2.058 moles of HI gas are introduced into an evacuated 4.60 liter flask at 250°C. Find the equilibrium concentrations of all the gases.

Use of K to Predict Effect of a Change in Conditions on an Equilibrium System

In Unit 2 we found that if a system in chemical equilibrium is altered in any way, the system will respond in such a way as to minimize the effect of the change. (Le Chatelier's principle)

Example 25. At a certain temperature in a 10.0 liter container, the equilibrium concentration of PCl_5 is 0.80 moles/liter, PCl_3 is 0.40 moles/l and Cl_2 is 0.10 moles/l. What would happen to the equilibrium state if

a) we add 2.00 moles PCl_5

or b) add 2.00 moles Cl_2

or c) decrease the volume to 5.0 liters?

Solution: a) $PCl_5(g) = PCl_3(g) + Cl_2(g)$

From the equilibrium concentration given, we can calculate the equilibrium constant:

$$K = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{(0.20)(0.20)}{(0.80)} = 0.050 .$$

At equilibrium, the number of moles of PCl_5 is

$$\frac{0.80 \text{ moles}}{\text{liter}} \times 10.0 \text{ liters} = 8.0 \text{ moles.}$$

The number of moles of PCl_3 is 4.0 moles and the number of moles of Cl_2 is 1.0 moles. If we now add 2.0 moles of PCl_5 the number of moles of PCl_5 will be 10.0. Using Le Chatelier's principle, we predict that upon addition of PCl_5 the equilibrium will shift in such a way as to relieve the stress, that is, by removal of PCl_5 to form more PCl_3 + Cl_2. Let y be the moles of PCl_3 formed.

	PCl_5 =	PCl_3 +	Cl_2
initial moles	10.00	4.0	1.0
new equil. moles	10 - y	4 + y	1 + y
equilibrium concentration	$\frac{10 - y}{10}$	$\frac{4 + y}{10}$	$\frac{1 + y}{10}$

What is the maximum value that y can have? ____

$$K = 0.050 = \frac{\left(\frac{4 + y}{10}\right)\left(\frac{1 + y}{10}\right)}{\left(\frac{10 - y}{10}\right)} = \frac{(4 + y)(1 + y)}{10(10 - y)}$$

$$0.50(10 - y) = (4 + y)(1 + y)$$

$$y^2 + 5.5y - 1 = 0$$

$$y = \frac{-5.5 \pm \sqrt{(5.5)^2 + 4}}{2}$$

$$= \frac{-5.5 \pm 5.8}{2} = \frac{0.3}{2} \text{ or } \frac{-11.3}{2}$$

y cannot be negative in this case since it is the number of moles of PCl_5 formed. So the right choice must be

$$y = \frac{0.3}{2} = 0.15 .$$

New equilibrium concentrations are:

$$[PCl_5] = \frac{10 - y}{10} = 0.985 \text{ moles/l}$$

$$[PCl_3] = \frac{4 + y}{10} = 0.415 \text{ moles/l}$$

$$[Cl_2] = \frac{1 + y}{10} = 0.115 \text{ moles/l} .$$

Note that when PCl_5 was added to it the system reacted in such a way as to relieve the stress, that is, by decreasing the PCl_5 concentration from 1.0 mole/l to 0.985 mole/l.

b) If, on the other hand, we had added 2.0 moles of Cl_2 to the system then the new number of moles of Cl_2 is 3.0 moles. According to Le Chatelier's principle the system would then react in such a way as to relieve the stress, that is, by decreasing the Cl_2 concentration. Thus, let y be the moles of PCl_5 formed and complete the table below:

	PCl_5	=	PCl_3	+	Cl_2
initial moles					
new equilibrium moles					
equilibrium concentration					

What is the maximum value that y can have? ____

Show that this leads to the quadratic equation

$y^2 - 7.5y + 8.0 = 0$ with roots $y = 1.32$ or 6.22.

Choose $y = 1.32$ since y cannot possibly be greater than 3.0. Thus, the new equilibrium state is:

$$[PCl_5] = \frac{8.0 + y}{10.0} = \frac{8.0 + 1.32}{10.0} = 0.932 \text{ moles/l}$$

$$[PCl_3] = \frac{4.0 - y}{10.0} = \frac{4.0 - 1.32}{10.0} = 0.268 \text{ moles/l}$$

$$[Cl_2] = \frac{3.0 - y}{10.0} = 0.168 \text{ moles/l} .$$

Note that when Cl_2 was added to it the system reacted in such a way as to relieve the stress, that is, by decreasing the concentration of Cl_2 from 0.30 moles/l to 0.168 moles/l.

c) Doubling the pressure will have the effect on a gaseous equilibrium of decreasing the volume to half of the original volume. Le Chatelier's principle predicts that the system will react in such a way as to try to relieve the stress. The stress in this case has the effect of increasing the concentration of all of the species. The system will try to decrease the total number of moles if it can. In cases where the number of moles of reactants and products in the chemical equation are different, then the equilibrium will shift in a direction which will decrease the total number of moles. In this chemical reaction, a decrease in volume will cause the equilibrium to shift to the left, by using up some PCl_3 and Cl_2 to form PCl_5.

Thus let y be the number of moles of PCl_5 formed. The new volume is 5.0 liters.

	$PCl_5(g)$ =	$PCl_3(g)$ +	$Cl_2(g)$
new equilibrium moles	$8.0 + y$	$4.0 - y$	$1.0 - y$
equilibrium concentration	$\frac{8.0 + y}{5.0}$	$\frac{4.0 - y}{5.0}$	$\frac{1.0 - y}{5.0}$

What is the maximum value that y can have?

$$K = 0.050 = \frac{\left(\frac{4.0 - y}{5.0}\right)\left(\frac{1.0 - y}{5.0}\right)}{\left(\frac{8.0 + y}{5.0}\right)} = \frac{(4.0 - y)(1.0 - y)}{5.0(8.0 + y)}$$

$$y^2 - 5.25y + 2.0 = 0$$

$$y = \frac{+5.25 \pm \sqrt{(5.25)^2 - 8.0}}{2} = \frac{5.25 \pm 4.42}{2}$$

$$y = \frac{0.83}{2} \text{ or } \frac{9.67}{2} .$$

Choose y = 0.83/2 = 0.415 because y cannot be greater than 1.0. The new equilibrium state will be:

$$[PCl_5] = \frac{8.0 + y}{5.0} = 8.415/5 = 1.683 \text{ moles/l}$$

$$[PCl_3] = \frac{4.0 - y}{5.0} = 3.585/5 = 0.717 \text{ moles/l}$$

$$[Cl_2] = \frac{1.0 - y}{5.0} = 0.585/5 = 0.177 \text{ moles/l} .$$

Note that the equilibrium shifted so as to decrease the concentrations when a decrease in volume was imposed on the system.

Another way to look at this effect in terms of pressure is the following:

> If the pressure is increased then the equilibrium will shift in the direction which will tend to decrease the pressure. Thus, the system shifts toward the direction with <u>fewer</u> molecules, in this case toward formation of PCl_5 from PCl_3 and Cl_2.

Had the reaction under study been one in which the number of moles of products equal the number of moles of reactant such as in

$$2\ HI(g) = H_2(g) + I_2(g)$$

2 total moles $\rightleftharpoons$ 2 total moles

then there can be no shift to a new equilibrium state. On the other hand in reactions such as:

$N_2(g) + 3\ H_2(g) = 2\ NH_3(g)$	4 moles $\rightleftharpoons$ 2 moles
$4\ HCl(g) + O_2(g) = 2\ H_2O(g) + 2\ Cl_2(g)$	5 moles $\rightleftharpoons$ 4 moles
$N_2O_4(g) + 2\ NO_2(g)$	1 mole $\rightleftharpoons$ 2 moles
$2\ NO(g) + O_2(g) = 2\ NO_2(g)$	3 moles $\rightleftharpoons$ 2 moles

there will be a shift toward the direction which will relieve an imposed decrease or increase in volume.

Note, however, that the only moles which count are those of species included in the equilibrium expression. Some examples:

$CaCO_3(s) = CaO(s) + CO_2(g)$	0 mole $\rightleftharpoons$ 1 mole
$Br_2(l) + H_2(g) = 2\ HBr(g)$	1 mole $\rightleftharpoons$ 2 moles

Use K to predict the effects of changes in conditions on the following systems

<u>Problem 26</u>. The following system is at equilibrium: $PCl_3 + Cl_2 \rightleftharpoons PCl_5$
At a total pressure of 2.71 atm the equilibrium concentrations are:

$[PCl_3] = 1.97 \times 10^{-2}$ M
$[Cl_2] = 1.97 \times 10^{-2}$ M
$[PCl_5] = 9.29 \times 10^{-2}$ M

If the pressure is changed to 5.10 atm at constant temperature, what will the new concentration of PCl_5 be equal to?

<u>Problem 27</u>. The equilibrium concentrations of the species in the reaction

$$C_2H_4 + HBr \rightleftharpoons C_2H_5Br$$

in a 4.40 liter container at 127°C are:

$[C_2H_4] = 8.31 \times 10^{-1}$ M
$[HBr] = 8.31 \times 10^{-1}$ M
$[C_2H_5Br] = 6.91 \times 10^{-4}$ M

If 0.81 moles of C_2H_4 is then introduced, find the new equilibrium concentration of C_2H_5Br.

CHECKING EQUILIBRIUM CALCULATIONS

In many problems involving chemical equilibrium the calculations become somewhat convoluted (students have even been known to say grotesque). Mistakes can occur. It is no sin to make errors -- but it is a sin not to realize it, especially when easy methods to check do exist.

There are two common symptoms of errors made in doing equilibrium calculations:

1. The total number of atoms of each type are found not to be the same when the calculation is finished as when it was started. This is usually a result of one or more very simple calculational mistakes.
2. The calculated equilibrium concentrations do not satisfy the equilibrium constant.

METHODS OF CHECKING CALCULATIONS

1. Conservation of Atoms:

Suppose we placed 10 moles of N_2 and 40 moles of H_2 in a container. Sometime later we might find 9 moles of N_2, 37 moles of H_2, and 2 moles of NH_3. The result has been that 1 mole of our original N_2 and 3 moles of our original H_2 have reacted to form 2 moles of NH_3 by the reaction:

$$N_2(g) + 3\ H_2(g) = 2\ NH_3(g)\ .$$

Nevertheless, even though the amounts of the various chemical species have changed, *the number of atoms are unchanged by any chemical reaction.* No atoms are gained or lost in a chemical reaction (really the law of conservation of mass). This provides a means to check for simple arithmetic errors.

		Initial	Later
N atoms:			
	No. of moles of N in N_2	$(2 \times 10) = 20$	$(2 \times 9) = 18$
	No. of moles of N in NH_3	0	2
	Total moles of N atoms	20	20
H atoms:			
	No. of moles of H in H_2	$(3 \times 40) = 120$	$(3 \times 37) = 111$
	No. of moles of H in NH_3	0	$(3 \times 3) = 9$
	Total moles of H atoms	120	120

Both the number of N and the number of H atoms remained constant in the reaction. This is always so. The above method always works. Technically you should check each atom in the equation -- but checking any one usually suffices.

2. *The Equilibrium State Always Satisfies the Equilibrium Constant:*

For the gas phase reaction

$$PCl_3(g) + Cl_2(g) = PCl_5(g) \qquad K = 24 \text{ (at } 300°C)$$

a typical problem might be: "Two moles of PCl_3 and one mole of Cl_2 are placed in a 10 liter container. What will be the equilibrium concentrations of PCl_3, Cl_2, and PCl_5?"

Suppose we carry out the calculation and find that our calculated values are:

$[PCl_3] = 0.14$ moles/l

$[Cl_2] = 0.04$ moles/l

$[PCl_5] = 0.06$ moles/l .

We <u>check</u> by seeing if Q = K. Only if it does have we calculated a set of concentrations which correspond to equilibrium.

$$Q = \frac{[PCl_5]}{[PCl_3][Cl_2]} = \frac{0.06}{(0.14)(0.04)} = 10.7$$

Clearly Q is not equal to K. There is definitely an error in the calculation we used to arrive at the above (supposed) equilibrium concentrations. The <u>correct</u> answers are:

$[PCl_3]_{eq} = 0.125$ moles/l

$[Cl_2]_{eq} = 0.025$ moles/l

$[PCl_5]_{eq} = 0.075$ moles/l .

The important thing is not so much to be error free, but to be able to recognize when errors have occurred.

Problem Set 1

1.

FOR THE EQUILIBRIUM:

$$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 4.345 MOLES OF BrCl
IN A 10-LITER FLASK.

2. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$$

IN A 5.25 LITER CONTAINER AT 127 DEG C ARE:
(C_2H_4) = 2.52E-01 M
(HBr) = 2.52E-01 M
(C_2H_5Br) = 6.37E-05 M
IF 1.96 MOLES OF C_2H_4 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF C_2H_5Br.

3.

FOR THE EQUILIBRIUM:

$$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .
1.915 MOLE EACH OF Br_2 AND Cl_2 GASES
ARE PLACED IN A 1.90 LITER FLASK AT 300 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE
ORIGINAL TOTAL PRESSURE.

4. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

AT A TOTAL PRESSURE OF 4.61 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(CO) = 3.72E-05 M
(Cl_2) = 3.72E-05 M
$(COCl_2)$ = 5.29E+00 M
IF THE PRESSURE IS CHANGED TO 3.10 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF $COCl_2$ BE EQUAL TO?

5. 0.905 MOLES OF BrCl IS PLACED IN A 4.00 LITER
FLASK AT 300 DEG C. WHEN THE CONTENTS HAVE COME TO
EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
FOR THE EQUILIBRIUM:

$$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .

6.

FOR THE EQUILIBRIUM:

$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$

THE EQUILIBRIUM CONSTANT IS : K = 2.500E-02 AT 1273 DEG K .
1.050 MOLES OF CO_2 ,1.593 MOLES OF CF_4
AND 2.037 MOLES OF COF_2 GAS ARE INTRODUCED
INTO AN EVACUATED 5.05 LITER FLASK AT 1000 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

7. WHEN THE SYSTEM

$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(PCl_3) = 3.39E-02 M
(Cl_2) = 3.39E-02 M
(PCl_5) = 2.75E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF PCl_5 ?

8. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$

ARE:
(I_2) = 5.30E-04 M
(Cl_2) = 5.30E-04 M
(ICl) = 2.37E-01 M
CALCULATE THE EQUILIBRIUM CONSTANT.

9. IF 2.615 MOLE OF SO_2 GAS AND 0.558 MOLE OF Cl_2
GAS ARE PLACED IN A 0.20 LITER TANK AT 127 DEG C,
HOW MANY MOLES OF SO_2Cl_2 WILL BE PRESENT
AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-03 AT 400 DEG K .

Problem Set 2

1. FOR THE EQUILIBRIUM:

$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$

THE EQUILIBRIUM CONSTANT IS : K = 1.480E+03 AT 900 DEG K .
0.270 MOLE EACH OF C_2H_4 AND H_2 GASES
ARE PLACED IN A 4.00 LITER FLASK AT 627 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE
ORIGINAL TOTAL PRESSURE.

2. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$

ARE:
(Br_2) = 6.46E-03 M
(Cl_2) = 6.46E-03 M
(BrCl) = 1.85E-01 M
CALCULATE THE EQUILIBRIUM CONSTANT.

3. FOR THE EQUILIBRIUM:

$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$

THE EQUILIBRIUM CONSTANT IS : K = 2.500E-02 AT 1273 DEG K .
4.870 MOLES OF CO_2 ,4.353 MOLES OF CF_4
AND 4.513 MOLES OF COF_2 GAS ARE INTRODUCED
INTO AN EVACUATED 4.30 LITER FLASK AT 1000 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

4. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$N_2 + O_2 \equiv\equiv\equiv 2\ NO$

IN A 1.20 LITER CONTAINER AT 2000 DEG C ARE:
(N_2) = 1.39E+00 M
(O_2) = 1.39E+00 M
(NO) = 4.39E-01 M
IF 0.56 MOLES OF N_2 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF NO.

5. WHEN THE SYSTEM

$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:

(C_2H_4) = 1.06E-02 M
(H_2) = 1.06E-02 M
(C_2H_6) = 1.67E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF C_2H_6 ?

6. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$N_2 + O_2 \equiv\equiv\equiv 2\ NO$$

AT A TOTAL PRESSURE OF 1.66 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(N_2) = 1.73E-01 M
(O_2) = 1.73E-01 M
(NO) = 5.47E-02 M
IF THE PRESSURE IS CHANGED TO 2.50 ATM AT CONSTANT TEMPERATURE, WHAT WILL THE NEW CONCENTRATION OF NO BE EQUAL TO?

7. FOR THE EQUILIBRIUM:

$$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E-02 AT 573 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 3.370 MOLES OF BrCl IN A 10-LITER FLASK.

8. 0.340 MOLES OF ICl IS PLACED IN A 4.90 LITER FLASK AT 25 DEG C. WHEN THE CONTENTS HAVE COME TO EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
FOR THE EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .

9. IF 2.405 MOLE OF C_2H_4 GAS AND 4.188 MOLE OF H_2 GAS ARE PLACED IN A 8.60 LITER TANK AT 627 DEG C, HOW MANY MOLES OF C_2H_6 WILL BE PRESENT AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

THE EQUILIBRIUM CONSTANT IS : K = 1.480E+03 AT 900 DEG K .

Problem Set 3

1. IF 4.490 MOLE OF H_2 GAS AND 0.353 MOLE OF I_2 GAS ARE PLACED IN A 9.90 LITER TANK AT 250 DEG C, HOW MANY MOLES OF HI WILL BE PRESENT AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$H_2 + I_2 \equiv\equiv\equiv 2\ HI$$

THE EQUILIBRIUM CONSTANT IS : K = 6.250E+02 AT 523 DEG K .

2. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$$

ARE:
(SO_2) = 7.90E-02 M
(Cl_2) = 7.90E-02 M
(SO_2Cl_2) = 6.24E-06 M
CALCULATE THE EQUILIBRIUM CONSTANT.

3. FOR THE EQUILIBRIUM:

$$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-03 AT 400 DEG K .
2.285 MOLE EACH OF C_2H_4 AND HBr GASES ARE PLACED IN A 4.45 LITER FLASK AT 127 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE ORIGINAL TOTAL PRESSURE.

4. FOR THE EQUILIBRIUM:

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

THE EQUILIBRIUM CONSTANT IS : K = 1.480E+03 AT 900 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 3.590 MOLES OF C_2H_6 IN A 10-LITER FLASK.

5. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

IN A 2.85 LITER CONTAINER AT 627 DEG C ARE:
(C_2H_4) = 2.19E-02 M
(H_2) = 2.19E-02 M
(C_2H_6) = 7.08E-01 M
IF 2.51 MOLES OF C_2H_4 IS THEN INTRODUCED, FIND THE NEW EQUILIBRIUM CONCENTRATION OF C_2H_6.

6. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

AT A TOTAL PRESSURE OF 3.21 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(I_2) = 6.62E-03 M
(Cl_2) = 6.62E-03 M
(ICl) = 2.96E+00 M
IF THE PRESSURE IS CHANGED TO 1.05 ATM AT CONSTANT TEMPERATURE, WHAT WILL THE NEW CONCENTRATION OF ICl BE EQUAL TO?

7. WHEN THE SYSTEM

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(C_2H_4) = 1.70E-02 M
(H_2) = 1.70E-02 M
(C_2H_6) = 4.28E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF C_2H_6 ?

8. 0.435 MOLES OF PCl_5 IS PLACED IN A 5.70 LITER FLASK AT 150 DEG C. WHEN THE CONTENTS HAVE COME TO EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES? FOR THE EQUILIBRIUM:

$$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$$

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+02 AT 423 DEG K .

9. FOR THE EQUILIBRIUM:

$$N_2 + O_2 \equiv\equiv\equiv 2\ NO$$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-01 AT 2273 DEG K .
3.015 MOLES OF N_2 ,0.917 MOLES OF O_2
AND 2.372 MOLES OF NO GAS ARE INTRODUCED
INTO AN EVACUATED 3.05 LITER FLASK AT 2000 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

Problem Set 4

1. WHEN THE SYSTEM

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
$(CO) = 5.37E\text{-}06$ M
$(Cl_2) = 5.37E\text{-}06$ M
$(COCl_2) = 1.10E\text{-}01$ M
WHAT IS THE DEGREE OF DISSOCIATION OF $COCl_2$?

2. FOR THE EQUILIBRIUM:

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

THE EQUILIBRIUM CONSTANT IS : $K = 1.480E+03$ AT 900 DEG K .
3.680 MOLE EACH OF C_2H_4 AND H_2 GASES
ARE PLACED IN A 3.70 LITER FLASK AT 627 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE
ORIGINAL TOTAL PRESSURE.

3. FOR THE EQUILIBRIUM:

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

THE EQUILIBRIUM CONSTANT IS : $K = 1.480E+03$ AT 900 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 4.495 MOLES OF C_2H_6
IN A 10-LITER FLASK.

4. FOR THE EQUILIBRIUM:

$$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$$

THE EQUILIBRIUM CONSTANT IS : $K = 2.500E\text{-}02$ AT 1273 DEG K .
1.620 MOLES OF CO_2 , 2.202 MOLES OF CF_4
AND 3.192 MOLES OF COF_2 GAS ARE INTRODUCED
INTO AN EVACUATED 5.10 LITER FLASK AT 1000 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

5. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

IN A 1.45 LITER CONTAINER AT 627 DEG C ARE:
$(C_2H_4) = 2.89E\text{-}02$ M
$(H_2) = 2.89E\text{-}02$ M

(C_2H_4) = 1.24E+00 M
IF 3.16 MOLES OF C_2H_4 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF C_2H_4.

6. IF 2.210 MOLE OF CO GAS AND 0.353 MOLE OF Cl_2 GAS ARE PLACED IN A 5.50 LITER TANK AT 100 DEG C, HOW MANY MOLES OF $COCl_2$ WILL BE PRESENT AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

THE EQUILIBRIUM CONSTANT IS : K = 3.830E+09 AT 373 DEG K .

7. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$N_2 + O_2 \equiv\equiv\equiv 2\ NO$$

AT A TOTAL PRESSURE OF 2.11 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(N_2) = 6.95E-01 M
(O_2) = 6.95E-01 M
(NO) = 2.20E-01 M
IF THE PRESSURE IS CHANGED TO 1.10 ATM AT CONSTANT TEMPERATURE, WHAT WILL THE NEW CONCENTRATION OF NO BE EQUAL TO?

8. 4.100 MOLES OF NO IS PLACED IN A 4.50 LITER FLASK AT 2000 DEG C. WHEN THE CONTENTS HAVE COME TO EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
FOR THE EQUILIBRIUM:

$$N_2 + O_2 \equiv\equiv\equiv 2\ NO$$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-01 AT 2273 DEG K .

9. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

ARE:
(CO) = 7.32E-06 M
(Cl_2) = 7.32E-06 M
$(COCl_2)$ = 2.05E-01 M
CALCULATE THE EQUILIBRIUM CONSTANT.

Problem Set 5

1. FOR THE EQUILIBRIUM:

$$H_2 + I_2 \equiv\equiv\equiv 2\ HI$$

THE EQUILIBRIUM CONSTANT IS : K = 6.250E+02 AT 523 DEG K .
3.650 MOLE EACH OF H_2 AND I_2 GASES
ARE PLACED IN A 5.30 LITER FLASK AT 250 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE
ORIGINAL TOTAL PRESSURE.

2. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$$

AT A TOTAL PRESSURE OF 1.86 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(C_2H_4) = 4.51E-01 M
(HBr) = 4.51E-01 M
(C_2H_5Br) = 2.03E-04 M
IF THE PRESSURE IS CHANGED TO 1.95 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF C_2H_5Br BE EQUAL TO?

3. 1.690 MOLES OF C_2H_6 IS PLACED IN A 5.10 LITER
FLASK AT 627 DEG C. WHEN THE CONTENTS HAVE COME TO
EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
FOR THE EQUILIBRIUM:

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

THE EQUILIBRIUM CONSTANT IS : K = 1.480E+03 AT 900 DEG K .

4. FOR THE EQUILIBRIUM:

$$H_2 + I_2 \equiv\equiv\equiv 2\ HI$$

THE EQUILIBRIUM CONSTANT IS : K = 6.250E+02 AT 523 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 0.430 MOLES OF HI
IN A 10-LITER FLASK.

5. IF 1.805 MOLE OF PCl_3 GAS AND 4.843 MOLE OF Cl_2
GAS ARE PLACED IN A 1.90 LITER TANK AT 150 DEG C,
HOW MANY MOLES OF PCl_5 WILL BE PRESENT
AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$$

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+02 AT 423 DEG K .

6. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$$

ARE:
(PCl_3) = 2.85E-02 M
(Cl_2) = 2.85E-02 M
(PCl_5) = 1.95E-01 M
CALCULATE THE EQUILIBRIUM CONSTANT.

7.

FOR THE EQUILIBRIUM:

$$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$$

THE EQUILIBRIUM CONSTANT IS : K = 2.500E-02 AT 1273 DEG K .
4.045 MOLES OF CO_2 ,4.567 MOLES OF CF_4
AND 0.957 MOLES OF COF_2 GAS ARE INTRODUCED
INTO AN EVACUATED 0.55 LITER FLASK AT 1000 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

8. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$$

IN A 3.85 LITER CONTAINER AT 127 DEG C ARE:
(C_2H_4) = 5.11E-01 M
(HBr) = 5.11E-01 M
(C_2H_5Br) = 2.62E-04 M
IF 3.11 MOLES OF C_2H_4 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF C_2H_5Br.

9. WHEN THE SYSTEM

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(C_2H_4) = 1.42E-02 M
(H_2) = 1.42E-02 M
(C_2H_6) = 3.00E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF C_2H_6 ?

Problem Set 6

1. FOR THE EQUILIBRIUM:

$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 2.915 MOLES OF ICl
IN A 10-LITER FLASK.

2. FOR THE EQUILIBRIUM:

$H_2 + I_2 \equiv\equiv\equiv 2\ HI$

THE EQUILIBRIUM CONSTANT IS : K = 6.250E+02 AT 523 DEG K .
2.980 MOLES OF H_2 ,0.183 MOLES OF I_2
AND 3.667 MOLES OF HI GAS ARE INTRODUCED
INTO AN EVACUATED 4.15 LITER FLASK AT 250 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

3. FOR THE EQUILIBRIUM:

$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-03 AT 400 DEG K .
0.650 MOLE EACH OF SO_2 AND Cl_2 GASES
ARE PLACED IN A 3.50 LITER FLASK AT 127 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE
ORIGINAL TOTAL PRESSURE.

4. 3.895 MOLES OF BrCl IS PLACED IN A 7.80 LITER
FLASK AT 300 DEG C. WHEN THE CONTENTS HAVE COME TO
EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
FOR THE EQUILIBRIUM:

$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .

5. IF 3.150 MOLE OF PCl_3 GAS AND 4.242 MOLE OF Cl_2
GAS ARE PLACED IN A 3.80 LITER TANK AT 150 DEG C,
HOW MANY MOLES OF PCl_5 WILL BE PRESENT
AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

PCl_3 + Cl_2 === PCl_5

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+02 AT 423 DEG K .

6. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

C_2H_4 + HBr === C_2H_5Br

AT A TOTAL PRESSURE OF 4.01 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(C_2H_4) = 8.09E-01 M
(HBr) = 8.09E-01 M
(C_2H_5Br) = 6.54E-04 M
IF THE PRESSURE IS CHANGED TO 4.70 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF C_2H_5Br BE EQUAL TO?

7. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

I_2 + Cl_2 === 2 ICl

ARE:
(I_2) = 1.03E-03 M
(Cl_2) = 1.03E-03 M
(ICl) = 4.61E-01 M
CALCULATE THE EQUILIBRIUM CONSTANT.

8. WHEN THE SYSTEM

I_2 + Cl_2 === 2 ICl

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(I_2) = 5.12E-04 M
(Cl_2) = 5.12E-04 M
(ICl) = 2.29E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF ICl ?

9. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

SO_2 + Cl_2 === SO_2Cl_2

IN A 5.15 LITER CONTAINER AT 127 DEG C ARE:
(SO_2) = 1.27E-01 M
(Cl_2) = 1.27E-01 M
(SO_2Cl_2) = 1.62E-05 M
IF 2.96 MOLES OF SO_2 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF SO_2Cl_2.

Problem Set 7

1.

FOR THE EQUILIBRIUM:

$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 2.070 MOLES OF BrCl
IN A 10-LITER FLASK.

2. WHEN THE SYSTEM

$CO + Cl_2 \equiv\equiv\equiv COCl_2$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
$(CO) = 1.03E\text{-}05$ M
$(Cl_2) = 1.03E\text{-}05$ M
$(COCl_2) = 4.09E\text{-}01$ M
WHAT IS THE DEGREE OF DISSOCIATION OF $COCl_2$?

3.

FOR THE EQUILIBRIUM:

$H_2 + I_2 \equiv\equiv\equiv 2\ HI$

THE EQUILIBRIUM CONSTANT IS : K = 6.250E+02 AT 523 DEG K .
4.815 MOLE EACH OF H_2 AND I_2 GASES
ARE PLACED IN A 1.95 LITER FLASK AT 250 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE
ORIGINAL TOTAL PRESSURE.

4. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$

AT A TOTAL PRESSURE OF 3.06 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
$(Br_2) = 2.32E\text{-}02$ M
$(Cl_2) = 2.32E\text{-}02$ M
$(BrCl) = 6.65E\text{-}01$ M
IF THE PRESSURE IS CHANGED TO 2.30 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF BrCl BE EQUAL TO?

5.

FOR THE EQUILIBRIUM:

$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .
0.870 MOLES OF I_2 ,0.018 MOLES OF Cl_2
AND 4.897 MOLES OF ICl GAS ARE INTRODUCED
INTO AN EVACUATED 3.00 LITER FLASK AT 25 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

6. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$C_2H_4 + HBr \equiv C_2H_5Br$$

IN A 4.80 LITER CONTAINER AT 127 DEG C ARE:
(C_2H_4) = 3.23E-01 M
(HBr) = 3.23E-01 M
(C_2H_5Br) = 1.04E-04 M
IF 2.51 MOLES OF C_2H_4 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF C_2H_5Br.

7. 4.435 MOLES OF ICl IS PLACED IN A 1.90 LITER FLASK AT 25 DEG C. WHEN THE CONTENTS HAVE COME TO EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
FOR THE EQUILIBRIUM:

$$I_2 + Cl_2 \equiv 2\ ICl$$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .

8. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$PCl_3 + Cl_2 \equiv PCl_5$$

ARE:
(PCl_3) = 1.66E-02 M
(Cl_2) = 1.66E-02 M
(PCl_5) = 6.64E-02 M
CALCULATE THE EQUILIBRIUM CONSTANT.

9. IF 4.025 MOLE OF H_2 GAS AND 3.742 MOLE OF I_2 GAS ARE PLACED IN A 5.00 LITER TANK AT 250 DEG C, HOW MANY MOLES OF HI WILL BE PRESENT AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$H_2 + I_2 \equiv 2\ HI$$

THE EQUILIBRIUM CONSTANT IS : K = 6.250E+02 AT 523 DEG K .

Problem Set 8

1. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

ARE:
$(CO) = 8.81E\text{-}06$ M
$(Cl_2) = 8.81E\text{-}06$ M
$(COCl_2) = 2.97E\text{-}01$ M
CALCULATE THE EQUILIBRIUM CONSTANT.

2. IF 1.480 MOLE OF I_2 GAS AND 4.013 MOLE OF Cl_2 GAS ARE PLACED IN A 3.10 LITER TANK AT 25 DEG C, HOW MANY MOLES OF ICl WILL BE PRESENT AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .

3.
FOR THE EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .
3.685 MOLE EACH OF I_2 AND Cl_2 GASES ARE PLACED IN A 4.10 LITER FLASK AT 25 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE ORIGINAL TOTAL PRESSURE.

4. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

IN A 5.10 LITER CONTAINER AT 627 DEG C ARE:
$(C_2H_4) = 2.24E\text{-}02$ M
$(H_2) = 2.24E\text{-}02$ M
$(C_2H_6) = 7.41E\text{-}01$ M
IF 2.91 MOLES OF C_2H_4 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF C_2H_6.

5. 2.165 MOLES OF BrCl IS PLACED IN A 1.60 LITER FLASK AT 300 DEG C. WHEN THE CONTENTS HAVE COME TO EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
FOR THE EQUILIBRIUM:

$$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .

6.

POR THE EQUILIBRIUM:

Br_2 + Cl_2 === 2 BrCl

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .
PIND THE DEGREE OP DISSOCIATION OP 3.610 MOLES OP BrCl
IN A 10-LITER PLASK.

7. THE POLLOWING SYSTEM IS AT EQUILIBRIUM:

Br_2 + Cl_2 === 2 BrCl

AT A TOTAL PRESSURE OP 0.86 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(Br_2) = 1.17E-02 M
(Cl_2) = 1.17E-02 M
(BrCl) = 3.33E-01 M
IP THE PRESSURE IS CHANGED TO 2.85 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OP BrCl BE EQUAL TO?

8. WHEN THE SYSTEM

I_2 + Cl_2 === 2 ICl

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(I_2) = 3.32E-04 M
(Cl_2) = 3.32E-04 M
(ICl) = 1.48E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OP ICl ?

9.

FOR THE EQUILIBRIUM:

Br_2 + Cl_2 === 2 BrCl

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .
1.010 MOLES OP Br_2 ,3.067 MOLES OP Cl_2
AND 3.107 MOLES OP BrCl GAS ARE INTRODUCED
INTO AN EVACUATED 3.65 LITER PLASK AT 300 DEG C.
PIND THE EQUILIBRIUM CONCENTRATIONS OP ALL THE GASES.

Problem Set 9

1. WHEN THE SYSTEM

$$H_2 + I_2 \equiv\equiv\equiv 2\ HI$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(H_2) = 1.58E-02 M
(I_2) = 1.58E-02 M
(HI) = 3.96E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF HI ?

2. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$H_2 + I_2 \equiv\equiv\equiv 2\ HI$$

IN A 2.00 LITER CONTAINER AT 250 DEG C ARE:
(H_2) = 7.92E-02 M
(I_2) = 7.92E-02 M
(HI) = 1.98E+00 M
IF 3.91 MOLES OF H_2 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF HI.

3. FOR THE EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .
0.630 MOLES OF I_2 ,4.372 MOLES OF Cl_2
AND 0.438 MOLES OF ICl GAS ARE INTRODUCED
INTO AN EVACUATED 1.60 LITER FLASK AT 25 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

4. 4.715 MOLES OF COF_2 IS PLACED IN A 1.40 LITER
FLASK AT 1000 DEG C. WHEN THE CONTENTS HAVE COME TO
EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
FOR THE EQUILIBRIUM:

$$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$$

THE EQUILIBRIUM CONSTANT IS : K = 2.500E-02 AT 1273 DEG K .

5. FOR THE EQUILIBRIUM:

$$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$$

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+02 AT 423 DEG K .
3.915 MOLE EACH OF PCl_3 AND Cl_2 GASES
ARE PLACED IN A 4.70 LITER FLASK AT 150 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE
ORIGINAL TOTAL PRESSURE.

6. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$$

ARE:
(SO_2) = 2.41E-01 M
(Cl_2) = 2.41E-01 M
(SO_2Cl_2) = 5.83E-05 M
CALCULATE THE EQUILIBRIUM CONSTANT.

7. FOR THE EQUILIBRIUM:

$$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 1.540 MOLES OF BrCl
IN A 10-LITER FLASK.

8. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

AT A TOTAL PRESSURE OF 4.06 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(CO) = 1.52E-05 M
(Cl_2) = 1.52E-05 M
$(COCl_2)$ = 8.79E-01 M
IF THE PRESSURE IS CHANGED TO 1.80 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF $COCl_2$ BE EQUAL TO?

9. IF 4.795 MOLE OF CO GAS AND 2.808 MOLE OF Cl_2
GAS ARE PLACED IN A 8.70 LITER TANK AT 100 DEG C,
HOW MANY MOLES OF $COCl_2$ WILL BE PRESENT
AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

THE EQUILIBRIUM CONSTANT IS : K = 3.830E+09 AT 373 DEG K .

Problem Set 10

FOR THE EQUILIBRIUM:

$$N_2 + O_2 \equiv\equiv\equiv 2\ NO$$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-01 AT 2273 DEG K .
3.850 MOLES OF N_2 ,4.987 MOLES OF O_2
AND 4.902 MOLES OF NO GAS ARE INTRODUCED
INTO AN EVACUATED 3.50 LITER FLASK AT 2000 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

2. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

AT A TOTAL PRESSURE OF 4.96 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(I_2) = 2.94E-03 M
(Cl_2) = 2.94E-03 M
(ICl) = 1.32E+00 M
IF THE PRESSURE IS CHANGED TO 1.75 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF ICl BE EQUAL TO?

3. IF 4.070 MOLE OF CO_2 GAS AND 1.317 MOLE OF CF_4
GAS ARE PLACED IN A 6.20 LITER TANK AT 1000 DEG C,
HOW MANY MOLES OF COF_2 WILL BE PRESENT
AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$$

THE EQUILIBRIUM CONSTANT IS : K = 2.500E-02 AT 1273 DEG K .

4. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$N_2 + O_2 \equiv\equiv\equiv 2\ NO$$

IN A 4.00 LITER CONTAINER AT 2000 DEG C ARE:
(N_2) = 2.00E-01 M
(O_2) = 2.00E-01 M
(NO) = 6.33E-02 M
IF 1.21 MOLES OF N_2 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF NO.

5. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

ARE:

(I_2) = 1.32E-04 M
(Cl_2) = 1.32E-04 M
(ICl) = 5.92E-02 M
CALCULATE THE EQUILIBRIUM CONSTANT.

6. 2.370 MOLES OF PCl_5 IS PLACED IN A 0.00 LITER FLASK AT 150 DEG C. WHEN THE CONTENTS HAVE COME TO EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES? FOR THE EQUILIBRIUM:

$$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$$

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+02 AT 423 DEG K .

7. FOR THE EQUILIBRIUM:

$$H_2 + I_2 \equiv\equiv\equiv 2\ HI$$

THE EQUILIBRIUM CONSTANT IS : K = 6.250E+02 AT 523 DEG K .
1.720 MOLE EACH OF H_2 AND I_2 GASES
ARE PLACED IN A 3.45 LITER FLASK AT 250 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE ORIGINAL TOTAL PRESSURE.

8. WHEN THE SYSTEM

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(CO) = 6.32E-06 M
(Cl_2) = 6.32E-06 M
$(COCl_2)$ = 1.53E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF $COCl_2$?

9. FOR THE EQUILIBRIUM:

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

THE EQUILIBRIUM CONSTANT IS : K = 3.830E+09 AT 373 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 3.165 MOLES OF $COCl_2$ IN A 10-LITER FLASK.

The CM Project

The Computer-enriched Module (CM) project is a collaborative effort by 19 faculty members in the disciplines of chemistry, mathematics and physics, to produce self-instructional computer-based materials at the introductory college level in those disciplines. Each module is designed to be usable in an academic environment with minimal computational facilities, and by students and faculty who are not programming experts. It may be used as an adjunct to standard textual materials, or in many cases, as a replacement for them. The primary aim of each module is to use the computer in such a way that students may take a more active role in the development and discovery of concepts and phenomena.

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TEACHER'S GUIDE TO

A MODULE ON CHEMICAL EQUILIBRIUM

UNIT 3. CHEMICAL EQUILIBRIUM CALCULATIONS

CYNTHIA J. JAMESON

UNIVERSITY OF ILLINOIS AT CHICAGO CIRCLE

a computer-enriched module

for introductory chemistry

featuring the programs

EQUIL

EQCALC

EQUIZ

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TEACHER'S GUIDE TO UNIT ON EQUILIBRIUM CALCULATIONS OF THE CHEMICAL EQUILIBRIUM MODULE

EDUCATIONAL OBJECTIVES

The objective is to enable the student to find quantitatively the extent of a reaction from its equilibrium constant, and the new equilibrium state reached upon changing conditions such as amounts of reactant or product, pressure or volume.

The methods used emphasize equilibrium calculations as simply another application of stoichiometry. The computer programs EQUIL and EQCALC use a trial and error method for finding the equilibrium state, using only stoichiometry and the definition of the equilibrium constant. The trial and error method allows the student to guess a value for the concentration of one of the components and he finds his own upper and lower bounds after each guess, just by comparing the concentration term with the equilibrium constant. In essence the student approaches the equilibrium state in a physically realistic manner. This eliminates problems such as choosing which root is physically meaningful. Algebraic methods, with emphasis on the stoichiometry are shown in examples in the student manual and exercises are provided. The EQUIZ program provides any number of problems and answers for student practice and self-test or for generating unit tests in a self-paced plan.

IMPLEMENTATION

This unit comes after Unit 1 and 2 of the equilibrium package or it may be used independently of these 2 units immediately after a definition of the equilibrium constant and a statement of Le Chatelier's principle.

Total time a student will spend on this unit will vary according to the number of problems which he will generate for himself to work on. Minimum time is probably 3 hours outside of terminal time. Terminal time required for single use of EQUIL is less than 20 minutes, for EQCALC is less than 10 minutes, for EQUIZ is 1 to 2 minutes.

This unit can be used for the following purposes:

1. as an adjunct to a lecture on chemical equilibrium.
2. as a review unit for a student in quantitative analysis or physical chemistry finding himself in these courses without a good background in equilibrium calculations.
3. as a first-exposure self-study unit for equilibrium calculations, assuming, of course, that a student has previously been exposed to the definition of the equilibrium constant and the statement of Le Chatelier's principle.
4. as a workbook or problems book to accompany a textbook.
5. as a unit for a self-paced course.

Depanding on the student's ability, he may or may not use EQUIZ to generate additional problems of the same type as those worked in the unit.

PROBLEM SOLUTIONS

Problem type:

FOR THE EQUILIBRIUM:

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

THE EQUILIBRIUM CONSTANT IS : K = 3.830E+09 AT 373 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 2.481 MOLES OF $COCl_2$
IN A 10-LITER FLASK.

Solution:

Let y = moles /l of CO at equilibrium.

CO	+	Cl_2	=	$COCl_2$
y		y		.2481 - y

$$K = 3.83 \times 10^9 = \frac{.2481 - y}{y^2}$$

$$3.83 \times 10^9 y^2 + y - .2481 = 0$$

$$y = \frac{-1 \pm \sqrt{1 + 4(.2481)(3.83 \times 10^9)}}{2 \times 3.83 \times 10^9} = \frac{-1 + 6.16 \times 10^4}{7.66 \times 10^9}$$

$$= 0.805 \times 10^{-5}$$

$$\text{degree of dissociation} = \frac{y}{.2481} = 3.24 \times 10^{-5}$$

Problem type:
WHEN THE SYSTEM

$$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
$(PCl_3) = 8.31E\text{-}02$ M
$(Cl_2) = 8.31E\text{-}02$ M
$(PCl_5) = 1.66E\text{-}01$ M
WHAT IS THE DEGREE OF DISSOCIATION OF PCl_5 ?

Solution:

$$PCl_3 + Cl_2 = PCl_5$$

$$.0831\ M \qquad .0831\ M \qquad .166\ M$$

if originally all PCl_5 then, initial $PCl_5 = (.166 + .0831) = .2491$

$$\text{degree of dissociation} = \frac{\text{dissociated amount}}{\text{initial amount}} = \frac{.0831}{.2491} = 0.334$$

Problem type:

AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$$

ARE:
$(C_2H_4) = 3.41E\text{-}01$ M
$(HBr) = 3.41E\text{-}01$ M
$(C_2H_5Br) = 1.16E\text{-}04$ M
CALCULATE THE EQUILIBRIUM CONSTANT.

Solution:

$$K = \frac{(C_2H_5Br)}{(C_2H_4)(HBr)} = \frac{1.16 \times 10^{-4}}{(3.41 \times 10^{-1})(3.41 \times 10^{-1})} = 0.001$$

Problem type:

2.555 MOLES OF $COCl_2$ IS PLACED IN A 0.06 LITER FLASK AT 100 DEG C. WHEN THE CONTENTS HAVE COME TO EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES? FOR THE EQUILIBRIUM:

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

THE EQUILIBRIUM CONSTANT IS : K = 3.830E+09 AT 373 DEG K .

Solution:

Let y = moles of Cl_2 at equilibrium:

CO	+	Cl_2	=	$COCl_2$	
$\frac{y}{.06}$		$\frac{y}{.06}$		$\frac{2.555 - y}{.06}$	equilibrium concentrations

$$K = 3.83 \times 10^9 = \frac{\left(\frac{2.555-y}{.06}\right)}{\left(\frac{y}{.06}\right)^2} = \frac{(2.555-y).06}{y^2}$$

$$3.83 \times 10^9\, y^2 + .06y - .1533 = 0$$

$$y = \frac{-.06 \pm \sqrt{.0036 + 4(.1533)(3.83\times10^9)}}{2(3.83 \times 10^9)}$$

Obviously, 0.06 will be very small compared to the square root term:

$$y \simeq \frac{4.85 \times 10^4}{7.66 \times 10^9} = .633 \times 10^{-5}$$

$(CO) = y/.06 = 1.055 \times 10^{-4}$ M

$(Cl_2) = 1.055 \times 10^{-4}$ M

$(COCl_2) = 2.555/.06 = 42.58$ M

Problem type:

IF 4.505 MOLE OF C_2H_4 GAS AND 4.617 MOLE OF HBr GAS ARE PLACED IN A 5.76 LITER TANK AT 127 DEG C, HOW MANY MOLES OF C_2H_5Br WILL BE PRESENT AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-03 AT 400 DEG K .

Solution:

Let y = moles C_2H_5Br at equilibrium.

C_2H_4	+	HBr	=	C_2H_5Br	
$\frac{4.505-y}{5.76}$		$\frac{4.617-y}{5.76}$		$\frac{y}{5.76}$	equil. concns.

$$K = .001 = \frac{(y/5.76)}{(\frac{4.505-y}{5.76})(\frac{4.617-y}{5.76})} = \frac{5.76\ y}{(4.505-y)(4.617-y)}$$

$$.001\ (4.505 - y)(4.617 - y) = 5.76\ y$$

$$.001\ y^2 - 5.77\ y + .0208 = 0$$

$$y = \frac{5.77 \pm \sqrt{(5.77)^2 - 4(.001)(.0208)}}{2\ (.001)}$$

Choose the negative root since y cannot be greater than 4.505 .

Or else, since y is probably very small compared to 4.505 or 4.617 , use the approximation

$$.001 \approx \frac{5.76\ y}{(4.505)(4.617)}\ , \quad \text{so} \quad y = \frac{.001(4.505)(4.617)}{5.76}$$

y = .0036 = moles of C_2H_5Br present at equilibrium.

Problem type:

FOR THE EQUILIBRIUM:

$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$

THE EQUILIBRIUM CONSTANT IS : K = 1.480E+03 AT 900 DEG K .

0.685 MOLES OF C_2H_4 ,0.172 MOLES OF H_2
AND 2.292 MOLES OF C_2H_6 GAS ARE INTRODUCED
INTO AN EVACUATED 0.26 LITER FLASK AT 627 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

Solution:

C_2H_4	+	H_2	=	C_2H_6	
.685		.172		2.292	initial moles

Place all moles in form of C_2H_4 and H_2:

(.685 + 2.292) (.172 + 2.292) 0

Let y = moles C_2H_6 at equilibrium

$\frac{(2.977 - y)}{.26}$	$\frac{(2.464 - y)}{.26}$	$\frac{y}{.26}$	equilibrium concentrations

$$K = 1480 = \frac{y/.26}{(\frac{2.977-y}{.26})(\frac{2.464-y}{.26})} = \frac{.26\,y}{(2.977-y)(2.464-y)}$$

$$(2.977-y)(2.464-y) = .26y/1480$$

$$y^2 - 5.443\,y + 7.335 = 0$$

$$y = \frac{5.443 \pm \sqrt{(5.443)^2 - 4(7.335)}}{2} = \frac{5.443 \pm \sqrt{.286}}{2}$$

y = 2.989 or y = 2.454 (y cannot be greater than 2.464)

$(C_2H_6) = y/.26 = 2.454/.26 = 9.44$ M

$(C_2H_4) = (2.977 - y)/.26 = 2.01$ M

$(H_2) = (2.464 - y)/.26 = .038$ M

Problem type:

FOR THE EQUILIBRIUM:

$$PCl_3 + Cl_2 \equiv\equiv PCl_5$$

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+01 AT 523 DEG K .
3.790 MOLE EACH OF PCl_3 AND Cl_2 GASES
ARE PLACED IN A 2.16 LITER FLASK AT 250 DEG C.
FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE ORIGINAL TOTAL PRESSURE.

Solution:

Let y = moles PCl_5 at equilibrium.

PCl_3	+	Cl_2	=	PCl_5	
3.790		3.790		0	total moles = 7.58
At equilibrium: 3.790 - y		3.790 - y		y	total moles = 7.58-y

$$\text{Ratio of } \frac{P_{tot} \text{ at equil}}{P_{tot} \text{ initial}} = \frac{7.58 - y}{7.58}$$

Find y:

$$K = 24 = \frac{y/2.16}{(\frac{3.790-y}{2.16})(\frac{3.790-y}{2.16})} = \frac{2.16\ y}{(3.790 - y)^2}$$

$$y^2 - 7.67\ y + 14.364 = 0$$

$$y = \frac{7.67 \pm \sqrt{(7.67)^2 - 4(14.364)}}{2} = \frac{7.67 \pm \sqrt{1.373}}{2}$$

$$y = 3.835 \pm .586$$

Take minus because y cannot be greater than 3.790 . Thus, y=3.249

$$\frac{P_{tot} \text{ at equil}}{P_{tot} \text{ initial}} = \frac{7.58 - 3.249}{7.58} = .571$$

Problem type:

THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$I_2 + Cl_2 \rightleftharpoons 2\ ICl$$

IN A 3.25 LITER CONTAINER AT 25 DEG C ARE:
(I_2) = 2.91E-03 M
(Cl_2) = 2.91E-03 M
(ICl) = 1.30E+00 M
IF 4.06 MOLES OF I_2 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF ICl.

Solution:

$$K = \frac{(1.30)^2}{(2.91 \times 10^{-3})^2} = 1.99 \times 10^5$$

I_2	+	Cl_2	=	2ICl
2.91×10^{-3} M		2.91×10^{-3} M		1.30 M

All moles converted into ICl:

0	0	$(1.30 + 2(2.91\times10^{-3}))3.25$ = 4.24 moles

Now add 4.06 moles of I_2:

4.06	0	4.24

Let y = equilibrium moles of Cl_2 .

$\frac{4.06 + y}{3.25}$	$\frac{y}{3.25}$	$\frac{4.24 - 2y}{3.25}$	equilibrium concentrations

$$K = 1.99 \times 10^5 = \frac{((4.24 - 2y)/3.25)^2}{(\frac{4.06+y}{3.25})(\frac{y}{3.25})} = \frac{(4.24-2y)^2}{(4.06+y)y}$$

Since K is very large, y must be small, use the approximation

$$1.99 \times 10^5 = \frac{(4.24)^2}{4.06y}$$

$$y = \frac{(4.24)^2}{1.99 \times 10^5(4.06)} = 2.21 \times 10^{-5}$$

$$(ICl) = \frac{4.24 - 2(2.21 \times 10^{-5})}{3.25} = \text{slightly less than } 1.30\ M$$

Problem type:

THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$SO_2 + Cl_2 \equiv\equiv SO_2Cl_2$$

AT A TOTAL PRESSURE OF 4.76 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(SO_2) = 1.04E+00 M
(Cl_2) = 1.04E+00 M
(SO_2Cl_2) = 1.09E-03 M
IF THE PRESSURE IS CHANGED TO 4.60 ATM AT CONSTANT TEMPERATURE, WHAT WILL THE NEW CONCENTRATION OF SO_2Cl_2 BE EQUAL TO?

Solution:

Let old volume = V liters. The pressure change leads to

new volume = $\frac{4.76}{4.60}$ V liters = 1.035 V liters

Convert all moles into reactant moles:

SO_2	+	Cl_2	=	SO_2Cl_2
1.041 M		1.041 M		0 M

Concentrations , using new volume :

$\frac{1.041V}{1.035V}$	$\frac{1.041V}{1.035V}$	0

Equilibrium concentrations :

$\frac{1.041}{1.035} - y$	$\frac{1.041}{1.035} - y$	y

$$K = \frac{1.09 \times 10^{-3}}{(1.04)^2} = \frac{y}{(1.0058 - y)^2}$$

From the given data, we know that y must be about 10^{-3} , which is small compared to 1.0058. Use the approximation:

$$1.00 \times 10^{-3} \approx \frac{y}{(1.0058)^2}$$

$$y = 1.01 \times 10^{-3} = (SO_2Cl_2)$$

ANSWERS TO PROBLEMS

3.2 2.50E-02

3.3 1.00E-03

3.9 $K = \frac{(.05)^2(.15)^6}{(.1)^4\ (.025)^3} = 18.22$

3.10 $K = \frac{(.56)^2}{(.04)^2(.72)} = 272.2$

3.11 $K = \frac{(.885)(.885)}{(1.115)(1.115)} = .63$

3.12 $K = \frac{(.030)^2(.030)^2}{(.015)^4(.018)} = 889.$

3.13 $K = \frac{(.075)^2(.0375)}{(.050)^2} = .0844$

3.14 $K = \frac{(.571)^3}{(1.429)^3} = .064$

3.17 3.27E-02

3.18 5.12E-01

3.19 8.97E-01

3.20 $[Br_2]$ = 1.32E-02 M
$[Cl_2]$ = 1.32E-02 M
[BrCl]= 3.78E-01 M

3.21 4.10E-05

3.23 $[I_2]$ = 1.34E+00 M
$[Cl_2]$ = 2.45E-05 M
[ICl] = 2.57E+00 M

3.24 $[H_2]$ = 9.49E-02 M
$[I_2]$ = 4.05E-03 M
[HI] = 4.90E-01 M

3.26 1.84E-01 M

3.27 8.44E-04 M

ANSWERS TO PROBLEM SETS

Set 1

1. 3.27E-02 M
2. 1.58E-04
3. 1.00E+00
4. 3.56E+00 M
5. $[Br_2]$ = 7.40E-03 M
   $[Cl_2]$ = 7.40E-03 M
   [BrCl] = 2.11E-01 M
6. $[CO_2]$ = 3.76E-01 M
   $[CF_4]$ = 4.83E-01 M
   $[COF_2]$ = 6.74E-02 M
7. 1.10E-01
8. 2.00E+05
9. 1.43E-04

Set 2

1. 5.48E-01
2. 8.17E+02
3. $[CO_2]$ = 1.54E+00 M
   $[CF_4]$ = 1.42E+00 M
   $[COF_2]$ = 2.34E-01 M
4. 4.98E-01 M
5. 5.98E-02
6. 8.23E-02 M
7. 3.27E-02
8. $[I_2]$ = 1.54E-04 M
   $[Cl_2]$ = 1.54E-04 M
   [ICl] = 6.91E-02 M
9. 2.40E+00

Set 3

1. 7.05E-01
2. 1.00E-03
3. 1.00E+00
4. 4.25E-02
5. 7.29E-01 M
6. 9.68E-01 M
7. 3.82E-02
8. $[PCl_3]$ = 1.59E-02 M
   $[Cl_2]$ = 1.59E-02 M
   $[PCl_5]$ = 6.04E-02 M
9. $[N_2]$ = 1.25E+00 M
   $[O_2]$ = 5.58E-01 M
   [NO] = 2.64E-01 M

Set 4

1. 4.92E-05
2. 5.13E-01
3. 3.80E-02
4. $[CO_2]$ = 5.80E-01 M
   $[CF_4]$ = 6.95E-01 M
   $[COF_2]$ = 1.00E-01 M
5. 1.27E+00 M
6. 3.53E-01
7. 1.14E-01 M
8. $[N_2]$ = 3.93E-01 M
   $[O_2]$ = 3.93E-01 M
   [NO] = 1.24E-01 M
9. 3.83E+09

Set 5

1. 1.00E+00
2. 2.23E-04 M
3. $[C_2H_4]$ = 1.46E-02 M
   $[H_2]$ = 1.46E-02 M
   $[C_2H_6]$ = 3.17E-01 M
4. 3.70E-02
5. 1.80E+00
6. 2.40E+02
7. $[CO_2]$ = 7.59E+00 M
   $[CF_4]$ = 8.54E+00 M
   $[COF_2]$ = 1.27E+00 M
8. 6.74E-04 M
9. 4.53E-02

Set 6

1. 2.23E-03
2. $[H_2]$ = 6.76E-01 M
   $[I_2]$ = 2.21E-03 M
   [HI] = 9.67E-01 M
3. 1.00E+00
4. $[Br_2]$ = 1.63E-02 M
   $[Cl_2]$ = 1.63E-02 M
   [BrCl] = 4.67E-01 M
5. 3.11E+00
6. 8.98E-04 M
7. 2.00E+05
8. 2.23E-03
9. 8.92E-05 M

Set 7

1. 3.27E-02
2. 2.54E-05
3. 1.00E+00
4. 4.99E-01 M
5. $[I_2]$ = 2.84E-01 M
   $[Cl_2]$ = 4.76E-05 M
   [ICl] = 1.64E+00 M
6. 2.73E-04 M
7. $[I_2]$ = 5.20E-03 M
   $[Cl_2]$ = 5.20E-03 M
   [ICl] = 2.32E+00 M
8. 2.40E+02
9. 7.13E+00

Set 8

1. 3.83E+09
2. 2.96E+00
3. 1.00E+00
4. 7.63E-01 M
5. $[Br_2]$ = 4.43E-02 M
   $[Cl_2]$ = 4.43E-02 M
   [BrCl] = 1.26E+00 M
6. 3.27E-02
7. 1.10E+00 M
8. 2.23E-03
9. $[Br_2]$ = 4.20E-03 M
   $[Cl_2]$ = 5.68E-01 M
   [BrCl] = 1.40E+00 M

Set 9

1. 3.70E-02
2. 2.13E+00 M
3. $[I_2]$ = 2.41E-06 M
   $[Cl_2]$ = 2.34E+00 M
   [ICl] = 1.06E+00 M
4. $[CO_2]$ = 1.56E+00 M
   $[CF_4]$ = 1.56E+00 M
   $[COF_2]$ = 2.47E-01 M
5. 5.34E-01
6. 1.00E-03
7. 3.27E-02
8. 3.90E-01 M
9. 2.81E+00

Set 10

1. $[N_2]$ = 1.53E+00 M
   $[O_2]$ = 1.86E+00 M
   [NO] = 5.34E-01 M
2. 4.64E-01 M
3. 3.35E-01
4. 9.48E-02 M
5. 2.00E+05
6. $[PCl_3]$ = 2.94E-02 M
   $[Cl_2]$ = 2.94E-02 M
   $[PCl_5]$ = 2.08E-01 M
7. 1.00 E+00
8. 4.18E-05
9. 2.89E-05

SOFTWARE

EQUIL

This tutorial program addresses itself to the problem:

$$A + B \rightleftarrows C \quad K = \ldots \text{ (all gases)}$$

Given initial number of moles of A and B in a 10 liter container, what are the equilibrium concentrations of A, B and C? The method used is iteration. After some introductory questions such as "What is the concentration of A before any reaction occurs?", the student determines the maximum possible concentration of C. He then makes an initial guess for [C] between 0 and this value. The concentrations of A and B and the concentration term which correspond to this guess for [C] are each calculated with some participation from the student and printed out. Depending on whether the concentration term is greater or smaller than K , student is asked to choose a smaller or larger guess for [C]. The new upper and lower limits obtained from previous guesses are imposed each time. Any guess outside these limits elicits a message to that effect: "From what you already done you know that [C] is between _____ and _____. Guess a value between these known limits." Because the concentration term and K are shown for each try, the student can see how far away he is from equilibrium. He generally can zero in on the acceptable correct value (taken to be within 5% of true value) within 5-6 tries.

There are 2 problems here. One is on $CO + Cl_2 = COCl_2$ in which $K < 1$ and another is on $PCl_3 + Cl_2$ in which $K \sim 20$. A student who does both reactions, very quickly realizes how different a system with $K < 1$ is from one in which K is very large.

EQCALC

This program allows the student to input the reactants and products, equilibrium constant and initial concentrations for any reaction of the type

$$4A + 5B = 3C + 2D$$

The program calculates the concentration term at each stage, allowing the student to choose a value for the concentration of a product so as to get a concentration term which is closer and closer to the constant of equilibrium for the reaction.

EQUIZ

This program generates quizzes on chemical equilibrium which the student may take off-line. The quizzes generated have the same problem types as those in the exercises and problem sets. The numbers and chemical systems are randomly chosen. A question mark asks for the quiz code number. The student types in a zero. He is then given the quiz code number and the quiz is printed out. If he wants the answers to his quiz he runs the program again but this time types in the quiz code number. Only the answers to his quiz will then be printed out.

Sample run of EQUIL

```
THERE ARE TWO PROBLEMS HERE. #1 WITH LARGE KEQ AND #2 WITH SMALL KEQ. YOU SHOULD TRY THEM BOTH
TO GET A FEELING FOR WHAT THE MAGNITUDE OF A CONSTANT OF EQUILIBRIUM MEANS.
WHICH PROBLEM WOULD YOU LIKE TO DO FIRST? TYPE THE NUMBER AND HIT THE RETURN KEY.
?2
CONSIDER THE REACTION:
     C12 + CO  ====  COC12    PHOSGENE

SUPPOSE WE PUT     1.1 MOLES OF C12
           AND     1.0 MOLES OF CO
           IN A  10.00 LITER CONTAINER.

BEFORE ANY REACTION OCCURS. WHAT IS THE CONCENTRATION (MOLES PER LITER) OF C12?
TYPE A NUMERICAL VALUE, THEN HIT RETURN
?.11
OK. NOW, WHAT IS THE CONCENTRATION (M/L) OF CO?
?.10
RIGHT! NOW ANSWER THIS QUESTION: WHAT IS THE MAXIMUM POSSIBLE CONCENTRATION (M/L) OF
PHOSGENE WHICH COULD FORM, ASSUMING THE REACTION PROCEEDS TO COMPLETION?
?.10
TRUE.  WE CANNOT HAVE MORE PHOSGENE FORMED THAN  1.0 MOLES OR A CONCENTRATION
OF  0.1000 M/L.  THERE ARE A CONSTANT NO. OF CHLORINE ATOMS IN THE CONTAINER.
IT IS IMPOSSIBLE TO DO BETTER THAN HAVE THEM ALL AS COC12. HENCE, WITHOUT KNOWING
K(EQ) AT ALL, WE KNOW THAT AT EQUILIBRIUM THE CONCENTRATION OF PHOSGENE IS BETWEEN
0 AND  0.1000 M/L.

SUPPOSE FOR C12+CO===COC12, K = 0.0444

WHERE K=(COC12)/(C12)(CO)= 0.0444 AT EQUILIBRIUM.

GIVEN K(EQ) WE WILL HAVE A SPECIFIC SET OF CONCENTRATIONS WHICH THE REACTANTS AND PRODUCTS CAN HAVE
    WE ALREADY KNOW THAT THE CONCENTRATION OF COC12 HAS TO BE BETWEEN 0 AND  0.10000 M/L.
SO YOU CAN GUESS THE CONCENTRATION OF PHOSGENE AT EQUILIBRIUM.  GIVEN K= 0.0444 GUESS A VALUE
FOR THE CONCENTRATION OF COC12 AT EQUILIBRIUM BETWEEN THE KNOWN LIMITS OF 0 AND  0.10000.
TYPE YOUR GUESS AND I WILL DO THE ARITHMETIC FOR YOU.
?.05
 IF (COC12)= 0.0500 THEN WE WANT TO KNOW WHAT THE CONCENTRATION OF C12 IS GOING TO BE.
ORIGINALLY, WE HAD A CONCENTRATION OF  0.1100 M/L. IF  0.0500 M/L OF COC12 FORM, THEN
BY HOW MANY MOLES PER LITER HAS THE CONCENTRATION OF C12 DIMINISHED?
ENTER A NUMBER AND RETURN.
?.05
```

```
RIGHT!
ALSO, THE CONCENTRATION OF CO HAS DIMINISHED BY THE SAME AMOUNT.
HENCE, YOU GUESS THAT EQUILIBRIUM OCCURS WHEN:
(COCl)= 0.0500 M/L
(Cl2 )= 0.0600 M/L
(CO  )= 0.0500 M/L
        (COCl2)/(Cl2)(CO) IS   ( 0.0500)/( 0.0600)( 0.0500)= 16.6667
GUESS AGAIN FOR THE EQUILIBRIUM VALUE OF (COCl2).
?.005
 IF (COCl2)= 0.0050 THEN WE WANT TO KNOW WHAT THE CONCENTRATION OF Cl2 IS GOING TO BE.
ORIGINALLY, WE HAD A CONCENTRATION OF  0.1100 M/L. IF  0.0050 M/L OF COCl2 FORM, THEN
BY HOW MANY MOLES PER LITER HAS THE CONCENTRATION OF Cl2 DIMINISHED?
ENTER A NUMBER AND RETURN.
?.005
RIGHT!
ALSO, THE CONCENTRATION OF CO HAS DIMINISHED BY THE SAME AMOUNT.
HENCE, YOU GUESS THAT EQUILIBRIUM OCCURS WHEN:
(COCl)= 0.0050 M/L
(Cl2 )= 0.1050 M/L
(CO  )= 0.0950 M/L
        (COCl2)/(Cl2)(CO) IS   ( 0.0050)/( 0.1050)( 0.0050)=  0.5013
GUESS AGAIN FOR THE EQUILIBRIUM VALUE OF (COCl2).
?.0005
THIS GUESS IS CLOSE ENOUGH.
THE EXACT VALUES ARE:
       (COCl2)    0.0005 MOLES/LITER
       (Cl2)     0.1095 MOLES/LITER
       (CO)     0.0995 MOLES/LITER
READY
```

18

Sample run of FOCALC

```
THIS PROGRAM HELPS YOU FIND EQUILIBRIUM
CONCENTRATIONS OF GASES IN REACTIONS OF THE TYPE:
     4A  +  3B  =  5C  +  2D
CHOOSE A REACTION.
TYPE 1 IF YOU WANT ME TO GIVE YOU SOME EXAMPLES, ELSE    TYPE 0
?0
WHAT IS ONE OF THE REACTANTS?HCl
THE OTHER REACTANT?O2
ONE OF THE PRODUCTS?Cl2
THE OTHER PRODUCT?H2O
NOW TELL ME THEIR COEFFICIENTS IN THE BALANCED
EQUATION, IN THE SAME ORDER
?4
?1
?2
?2
ALL CONCENTRATIONS WILL BE EXPRESSED IN MOLES/LITER.
WHAT IS THE INITIAL CONCENTRATION OF HCl?4.0
WHAT IS THE INITIAL CONCENTRATION OF O2?5.0
WHAT IS THE EQUILIBRIUM CONSTANT?50.0
WHAT IS THE MAXIMUM VALUE FOR THE EQUILIBRIUM CONCENTRATION OF Cl2?2.0
GUESS A VALUE FOR THE EQUILIBRIUM CONCENTRATION OF Cl2:
?1.5
HENCE, YOU GUESS THAT EQUILIBRIUM OCCURS WHEN:
(Cl2 )= 1.500E+00 MOLES/L
(H2O )= 1.500E+00 MOLES/L
(HCl )= 1.000E+00 MOLES/L
(O2  )= 4.250E+00 MOLES/L
    (Cl2)2(H2O)2/(HCl)4(O2)1 IS   ( 2.250E+00)( 2.250E+00)/( 1.000E+00)( 4.250E+00)= 1.19117E+00
GUESS AGAIN FOR THE EQUILIBRIUM VALUE OF (Cl2).
?1.6
HENCE, YOU GUESS THAT EQUILIBRIUM OCCURS WHEN:
(Cl2 )= 1.600E+00 MOLES/L
(H2O )= 1.600E+00 MOLES/L
(HCl )= 8.000E-01 MOLES/L
(O2  )= 4.200E+00 MOLES/L
    (Cl2)2(H2O)2/(HCl)4(O2)1 IS   ( 2.560E+00)( 2.560E+00)/( 4.096E-01)( 4.200E+00)= 3.80949E+00
GUESS AGAIN FOR THE EQUILIBRIUM VALUE OF (Cl2).
?1.4
```

```
FROM WHAT YOU HAVE ALREADY DONE YOU KNOW THAT THE CONCENTRATION OF   C12
IS BETWEEN    1.600E+00 MOLES/L   AND     2.000E+00 MOLES/L
GUESS A VALUE BETWEEN THESE KNOWN LIMITS.
?1.8
THE CONCENTRATION TERM THIS TIME IS          1.000E+02
IT IS SOMEWHAT  LARGER   THAN THE KEQ        5.000E+01
HENCE WE NEED A VALUE OF THE CONCENTRATION OF C12 WHICH IS  SMALLER
WHAT IS YOUR GUESS?
?1.75
THE CONCENTRATION TERM THIS TIME IS          3.038E+01
IT IS SOMEWHAT  SMALLER  THAN THE KEQ        5.000E+01
HENCE WE NEED A VALUE OF THE CONCENTRATION OF C12 WHICH IS  LARGER
WHAT IS YOUR GUESS?
?1.77
THE CONCENTRATION TERM THIS TIME IS          5.327E+01
IT IS SOMEWHAT  LARGER   THAN THE KEQ        5.000E+01
HENCE WE NEED A VALUE OF THE CONCENTRATION OF C12 WHICH IS  SMALLER
WHAT IS YOUR GUESS?
?1.76
THE CONCENTRATION TERM THIS TIME IS          4.387E+01
IT IS SOMEWHAT  SMALLER  THAN THE KEQ        5.000E+01
HENCE WE NEED A VALUE OF THE CONCENTRATION OF C12 WHICH IS  LARGER
WHAT IS YOUR GUESS?
?1.765
THIS GUESS IS CLOSE ENOUGH.
THE EXACT VALUES ARE:
       (C12)    1.766E+00 MOLES/LITER
       (H2O)    1.766E+00 MOLES/LITER
       (HCl)    4.677E-01 MOLES/LITER
       (O2)    4.117E+00 MOLES/LITER
READY
```

Sample run of EQUIZ to generate a quiz

```
?0
QUIZ    287
   1.  IF 2.550 MOLE OF CO GAS AND 1.742 MOLE OF Cl2
       GAS ARE PLACED IN A 5.50 LITER TANK AT  100 DEG C,
       HOW MANY MOLES OF COCl2 WILL BE PRESENT
       AT EQUILIBRIUM?
       FOR THE EQUILIBRIUM:

            CO   +    Cl2 ===  COCl2

       THE EQUILIBRIUM CONSTANT IS :  K =  3.83E+09 AT  373 DEG K .

   2.
       FOR THE EQUILIBRIUM:

            CO   +    Cl2 ===  COCl2

       THE EQUILIBRIUM CONSTANT IS :  K =  3.83E+09 AT  373 DEG K .
       FIND THE DEGREE OF DISSOCIATION OF 2.475 MOLES OF COCl2
       IN A 10-LITER FLASK.

   3.  3.020 MOLES OF ICl IS PLACED IN A 1.90 LITER
       FLASK AT   25 DEG C.  WHEN THE CONTENTS HAVE COME TO
       EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
       FOR THE EQUILIBRIUM:

            I2   +    Cl2 === 2 ICl

       THE EQUILIBRIUM CONSTANT IS :  K =  2.00E+05 AT  298 DEG K .


   4.  FOR THE EQUILIBRIUM:

            N2   +    O2 === 2 NO

       THE EQUILIBRIUM CONSTANT IS :  K =  1.00E-01 AT 2273 DEG K .
       3.025 MOLE EACH OF N2 AND O2 GASES
       ARE PLACED IN A 4.00 LITER FLASK AT 2000 DEG C.
       FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE
       ORIGINAL TOTAL PRESSURE.

   5.  WHEN THE SYSTEM

            Br2   +    Cl2 === 2 BrCl

       IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
         (Br2) =  7.05E-03 M
         (Cl2) =  7.05E-03 M
         (BrCl) =  2.01E-01 M
       WHAT IS THE DEGREE OF DISSOCIATION OF BrCl ?
```

6. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

PC13 + C12 === PC15

IN A 2.65 LITER CONTAINER AT 150 DEG C ARE:
(PC13) = 7.41E-02 M
(C12) = 7.41E-02 M
(PC15) = 1.32E+00 M
IF 3.01 MOLES OF PC13 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF PC15.

7. FOR THE EQUILIBRIUM:

C2H4 + HBr === C2H5Br

THE EQUILIBRIUM CONSTANT IS : K = 1.00E-03 AT 400 DEG K .
3.805 MOLES OF C2H4 ,4.808 MOLES OF HBr
AND 0.127 MOLES OF C2H5Br GAS ARE INTRODUCED
INTO AN EVACUATED 1.40 LITER FLASK AT 127 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

8. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

CO + C12 === COC12

AT A TOTAL PRESSURE OF 0.78 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(CO) = 5.53E-06 M
(C12) = 5.53E-06 M
(COC12) = 1.17E-01 M
IF THE PRESSURE IS CHANGED TO 1.30 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF COC12 BE EQUAL TO?

9. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

Br2 + C12 === 2 BrCl

ARE:
(Br2) = 3.17E-03 M
(C12) = 3.17E-03 M
(BrCl) = 9.06E-02 M
CALCULATE THE EQUILIBRIUM CONSTANT.

READY

Sample run of EQUIZ to generate the answers

```
?287
     1.  1.74E+00
     2.  3.28E-05
       (I2) =  3.74E-03 M
       (C12) =  3.74E-03 M
       (IC1) =  1.67E+00 M
     3.
     4.  1.00E+00
     5.  3.27E-02
     6.  1.39E+00
       (C2H4) =  2.80E+00 M
       (HBr) =  3.51E+00 M
       (C2H5Br) =  8.84E-03 M
     7.
     8.  1.94E-01 M/L
     9.  8.17E+02
READY
```

```
00010   REM EQUIL EQUILIBRIUM CALCULATIONS
00020   REM WRITTEN BY CYNTHIA JAMESON UNIV OF ILLINOIS
00030   REM CHICAGO CIRCLE BOX 4348 CHICAGO 60680
00040   REM FOR UNIT 3 OF EQUILIBRIUM MODULE IIT,AUG 1974
00050  DIM S$(5),R$(2,5),K2(2)
00060  DATA 18.86,"PCL3","CL2","PCL5","PHOSPHORUS"
00070  DATA "PHOSPHORUS PENTACHLORIDE",.0444,"CL2","CO"
00080  DATA "COCL2","CHLORINE","PHOSGENE"
00090  FOR I=1 TO 2
00100  READ K(I)
00110  FOR J=1 TO 5
00120  READ R$(I,J)
00130  NEXT J
00140  NEXT I
00150  PRINT "THERE ARE TWO PROBLEMS HERE, #1 WITH LARGE KEQ";
00155  PRINT " AND #2 WITH SMALL KEQ. YOU SHOULD TRY THEM BOTH."
00160  PRINT "TO GET A FEELING FOR WHAT THE MAGNITUDE OF";
00170  PRINT "A CONSTANT OF EQUILIBRIUM MEANS."
00180  PRINT "WHICH PROBLEM WOULD YOU LIKE TO DO FIRST?";
00190  PRINT "TYPE THE NUMBER AND HIT THE RETURN KEY."
00200  INPUT X
00210  IF X<=2 AND X>=1 THEN 240
00220  PRINT "PLEASE TYPE A NUMBER 1 OR 2."
00230  GO TO 200
00240  K=K2(X)
00250  FOR I=1 TO 5
00260  S$(I)=R$(X,I)
00270  NEXT I
00280  PRINT "CONSIDER THE REACTION:"
00290  PRINT "     ";S$(1);" + ";S$(2);"  ==== ";
00300  PRINT S$(3);"    ";S$(5)
00310  PRINT
00320  G=RND(-1)*90+10
00330  M1=INT(G)/10
00340  G=RND(0)*50+10
00350  M2=INT(G)/10
00360  IF M2>M1 THEN 340
00370  PRINT "SUPPOSE WE PUT   ";M1;" MOLES OF ";S$(1)
00380  PRINT "           AND  ";M2;" MOLES OF ";S$(2)
00390  PRINT "           IN A 10.0 LITER CONTAINER."
00400  PRINT
00410  PRINT
00420  PRINT
00430  PRINT "BEFORE ANY REACTION OCCURS, WHAT IS THE";
00440  PRINT " CONCENTRATION (MOLES PER LITER) OF ";S$(1);"?"
00450  PRINT "TYPE A NUMERICAL VALUE, THEN HIT RETURN"
00460  INPUT X
00470  R1=M1/10
00480  IF X<.95*R1 THEN 1680
00490  IF X>1.05*R1 THEN 1680
00500  PRINT "OK. NOW, WHAT IS THE CONCENTRATION OF ";S$(2),"?"
```

```
00510  L1=0
00520  INPUT X
00530  R2=M2/10
00540  IF X>.95*R2 AND X<1.05*R2 THEN 590
00550  L1=L1+1
00560  IF L1<2 THEN 1770
00570  IF L1=2 THEN 1820
00580  IF L1>2 THEN 1870
00590  PRINT "RIGHT! NOW ANSWER THIS QUESTION: WHAT IS THE ";
00600  PRINT "MAXIMUM POSSIBLE CONCENTRATION OF"
00610  PRINT S$(5);" WHICH COULD FORM, ASSUMING THE REACTION ";
00620  PRINT "PROCEEDS TO COMPLETION?"
00630  L1=0
00640  INPUT X
00650  IF X>.95*R2 AND X<1.05*R2 THEN 690
00660  L1=L1+1
00670  IF L1<2 THEN 1890
00680  IF L1=2 THEN 1950
00690  PRINT "TRUE.  WE CANNOT HAVE MORE ";S$(5);
00700  PRINT " FORMED THAN ";M2;" MOLES OR A CONCENTRATION"
00710  PRINT "OF ";R2; M/L. THERE ARE A CONSTANT NO. OF ";
00720  PRINT S$(4);" ATOMS IN THE CONTAINER."
00730  PRINT "IT IS IMPOSSIBLE TO DO BETTER THAN HAVE THEM ALL AS ";
00740  PRINT S$(3); ". HENCE, WITHOUT KNOWING"
00750  PRINT "K AT ALL, WE KNOW THAT AT EQUILIBRIUM THE CONCENTRATION OF ";
00760  PRINT S$(5);" IS BETWEEN"
00770  PRINT "0 AND ";R2;" MOLES/LITER."
00780  PRINT
00790  PRINT "SUPPOSE FOR ";S$(1);"+";S$(2);"===";
00800  PRINT S$(3); ", K =";K
00810  PRINT
00820  PRINT "WHERE K=(";S$(3);")/(";S$(1);")(";S$(2);
00830  PRINT ")=";K;" AT EQUILIBRIUM."
00840  PRINT
00850  PRINT "GIVEN K WE WILL HAVE A SPECIFIC SET OF ";
00860  PRINT "CONCENTRATIONS WHICH THE REACTANTS AND PRODUCTS CAN HAVE."
00870  PRINT
00880  PRINT "WE ALREADY KNOW THAT THE CONCENTRATION OF ";
00890  PRINT S$(3);" HAS TO BE BETWEEN 0 AND ";R2;"MOLES/L."
00900  PRINT "SO YOU CAN GUESS THE CONCENTRATION OF ";S$(5);
00910  PRINT "AT EQUILIBRIUM.  GIVEN K=";K;" GUESS A VALUE"
00920  PRINT "FOR THE CONCENTRATION OF ";S$(3);
00930  PRINT " AT EQUILIBRIUM BETWEEN THE KNOWN LIMITS OF 0 AND ";R2
00940  PRINT "TYPE YOUR GUESS AND I WILL DO THE ARITHMETIC FOR YOU."
00950  A=K
00960  L=M=0
00970  N=R2
00980  L=L+1
00990  INPUT X
01000  IF X<=M THEN 1980
```

```
01010  IF X>=N THEN 1980
01020  GOSUB 2030
01030  B$=" LARGER "
01040  C$=" SMALLER "
01050  IF Q<.95*A THEN 1080
01060  IF Q>1.05*A THEN 1120
01070  GO TO 1500
01080  D$=C$
01090  E$=B$
01100  P=N
01110  GO TO 1150
01120  D$=B$
01130  E$=C$
01140  P=M
01150  IF L<3 THEN 1240
01170  PRINT "THE CONCENTRATION TERM THIS TIME IS     ";Q
01180  PRINT "IT IS SOMEWHAT ";D$;" THAN THE KEQ     ";K
01190  PRINT "HENCE WE NEED A VALUE OF THE CONCENTRATION OF ";
01200  PRINT S$(3);" WHICH IS ";E$
01210  PRINT "WHAT IS YOUR GUESS?"
01220  GOSUB 2070
01230  GO TO 980
01240  PRINT "IF (";S$(3);")=";X;" THEN WE WANT TO KNOW WHAT";
01250  PRINT "THE CONCENTRATION OF ";S$(1);" IS GOING TO BE."
01260  PRINT "ORIGINALLY, WE HAD A CONCENTRATION OF ";R1;
01270  PRINT "M/L. IF ";X;" M/L OF ";S$(3);" FORM, THEN"
01280  PRINT "BY HOW MANY MOLES PER LITER HAS THE CONCENTRATION OF ";
01290  PRINT S$(1);" DIMINISHED?"
01300  PRINT "ENTER A NUMBER AND RETURN."
01310  G=X
01320  INPUT X
01330  IF G=X THEN 1370
01340  X=G
01350  PRINT "WRONG! THE ANSWER IS ";X
01360  GO TO 1380
01370  PRINT "RIGHT!"
01380  PRINT "ALSO THE CONCENTRATION OF ";S$(2);
01390  PRINT " HAS DIMINISHED BY THE SAME AMOUNT."
01400  PRINT "HENCE YOU GUESS THAT EQUILIBRIUM OCCURS WHEN:"
01410  PRINT "(";S$(3);")=";X;" M/L"
01420  PRINT "(";S$(1);")=";Y;" M/L"
01430  PRINT "(";S$(2);")=";Z;" M/L"
01440  PRINT "(";S$(3);")/(";S$(1);")(";S$(2);
01450  PRINT ") IS  (";X;")/(";Y;")(";Z;")=";Q
01460  GOSUB 2070
01470  PRINT "GUESS AGAIN FOR THE EQUILIBRIUM VALUE OF (";
01480  PRINT S$(3);")."
01490  GO TO 980
01500  PRINT "THIS GUESS IS CLOSE ENOUGH."
```

```
01510  PRINT "THE EXACT VALUES ARE:"
01520  X1=X
01530  Q1=Q
01540  X=1.02*X1
01550  GOSUB 2030
01560  IF Q1=Q THEN 1620
01570  X2=X+(X1-X)/(Q1-Q)*(K-Q)
01580  X1=X
01590  X=X2
01600  Q1=Q
01610  IF X1#X THEN 1550
01620  PRINT "    (";S$(3);")  =";X;" MOLES/LITER"
01630  C1=R1-X
01640  PRINT "    (";S$(1);")  =";C1;" MOLES/LITER"
01650  C1=R2-X
01660  PRINT "    (";S$(2);")  =";C1;" MOLES/LITER"
01670  STOP
01680  PRINT "WRONG! REMEMBER, WE PUT ";M1;" MOLES OF ";
01690  PRINT S$(1);" INTO A 10.0 LITER CONTAINER."
01700  PRINT "THE CONCENTRATION OF ";S$(1);
01710  PRINT " EXPRESSED IN MOLES/LITER IS:"
01720  PRINT "  ";M1;" MOLES ";S$(1);"/10 LITERS =";
01730  PRINT M1;/10 =";R1
01740  PRINT "NOW GO BACK AND ENTER THE CORRECT ANSWER THIS TIME."
01750  PRINT "ENTER ";R1;", THEN HIT THE RETURN KEY."
01760  GO TO 460
01770  PRINT "YOU ARE WRONG! CONSIDER, WITH RESPECT TO ";S$(2);
01780  PRINT ", WE PUT ";M2;" MOLE IN A TEN LITER CONTAINER."
01790  PRINT "WE ARE ASKING FOR THE NUMBER OF MOLES PER LITER.";
01800  PRINT "ENTER ANOTHER ANSWER AND HIT THE RETURN KEY."
01810  GO TO 520
01820  PRINT "TAKE SOME TIME AND BE SURE YOU UNDERSTAND THE ABOVE."
01830  PRINT M2;" MOLE ";S$(2);"/10 LITERS =";M2;"/10 = ";R2
01840  PRINT "PRACTICE PUTTING CONCENTRATION QUESTIONS IN THIS FORM."
01850  PRINT "ENTER ";R2;" THEN HIT THE RETURN KEY."
01860  GO TO 520
01870  PRINT "DO NOT PLAY AROUND! FOLLOW INSTRUCTIONS!"
01880  GO TO 1850
01890  PRINT "WRONG!"
01900  PRINT " FOR:      ";S$(1);" + ";S$(2);" === ";S$(3)
01910  PRINT "      ";M1;"  ";M2;"         X"
01920  PRINT "       X IS OBVIOUSLY LIMITED BY (";S$(2);")"
01930  PRINT "NOW, TRY AGAIN."
01940  GO TO 640
01950  PRINT "I AM SORRY, YOU ARE WRONG AGAIN."
01960  PRINT "PLEASE COME BACK AFTER YOU HAVE STUDIED SOME MORE."
01970  STOP
01980  PRINT "FROM WHAT YOU HAVE ALREADY DONE YOU KNOW ";
01990  PRINT "THAT THE CONCENTRATION OF ";S$(3)
02000  PRINT "IS BETWEEN     ";M; M/L  AND    ";N;" M/L"
```

```
02010  PRINT "GUESS A VALUE BETWEEN THESE KNOWN LIMITS."
02020  GO TO 990
02030  Y=R1-X
02040  Z=R2-X
02050  Q=X/(Y*Z)
02060  RETURN
02070  IF P=N THEN 2100
02080  N=X
02090  GO TO 2110
02100  M=X
02110  RETURN
02120  END
END OF DATA
```

EQCALC

```
00010 REM EQCALC EQUILIBRIUM CALCULATIONS
00020 REM WRITTEN BY CYNTHIA JAMESON UNIV OF ILLINOIS
00030 REM CHICAGO CIRCLE BOX 4348 CHICAGO 60680
00040 REM FOR UNIT 3 OF EQUILIBRIUM MODULE IIT,AUG 1974
00050  DIM N(4),S$(4)
00060 PRINT "THIS PROGRAM HELPS YOU FIND EQUILIBRIUM "
00070 PRINT "CONCENTRATIONS OF GASES IN REACTIONS OF THE TYPE:"
00080  PRINT " 4A  +  3B  =  5C  +  2D"
00090   PRINT "CHOOSE A REACTION."
00100 PRINT "TYPE 1 IF YOU WANT ME TO GIVE EXAMPLES, ELSE TYPE 0";
00110  INPUT X
00120  IF X=0 THEN 130
00125  GOSUB 1210
00130  PRINT "WHAT IS ONE OF THE REACTANTS? ";
00140  INPUT S$(1)
00150  PRINT "THE OTHER REACTANT? ";
00160  INPUT S$(2)
00170  PRINT "ONE OF THE PRODUCTS? ";
00180  INPUT S$(3)
00190  PRINT "THE OTHER PRODUCT? ";
00200  INPUT S$(4)
00210  PRINT "NOW TELL ME THEIR COEFFICIENTS IN THE BALANCED"
00220   PRINT "EQUATION, IN THE SAME ORDER"
00230   FOR I=1 TO 4
00240  INPUT X
00250  N(I)=X
00260  NEXT I
00270   PRINT "ALL CONCENTRATIONS WILL BE EXPRESSED IN MOLES/LITER."
00280   PRINT "WHAT IS THE INITIAL CONCENTRATION OF ";S$(1);"? ";
00290  INPUT M1
00300   PRINT "WHAT IS THE INITIAL CONCENTRATION OF ";S$(2);"? ";
00310  INPUT M2
00320 PRINT "WHAT IS THE EQUILIBRIUM CONSTANT? ";
00330   INPUT A
00340 PRINT "WHAT IS THE MAXIMUM VALUE FOR THE EQUILIBRIUM"
00350   PRINT " CONCENTRATION OF ";S$(3);"? ";
00360  INPUT D
00370  LET X=MIN(N(3)/N(1)*M1,N(3)/N(2)*M2)
00380 IF D>.99*X  AND  D<1.01*X THEN 420
00390  LET D=X
00400 PRINT "NO, IT IS ";D
00410  REM  THE STUDENT GUESSES A VALUE FOR THE CONCENTRATION OF PRODUCT
00420 PRINT "GUESS A VALUE FOR THE EQUILIBRIUM CONCENTRATION OF ";S$(3)
00430  LET L=0
00440  LET C=0
00450   LET L=L+1
00460  INPUT X
00470  IF X<=C THEN 1050
00480  IF X>=D THEN 1050
00490  GOSUB 1100
00500   B$=" LARGER  "
```

```
00510  C$=" SMALLER "
00520  IF Q<A-.05*A THEN 550
00530  IF Q>A+.05*A THEN 600
00540  GO TO 850
00550    D$=C$
00560  E$=B$
00570  LET B=D
00580  IF L<3 THEN 720
00590  GO TO 650
00600   D$=B$
00610  E$=C$
00620  LET B=C
00630  IF L=1 THEN 720
00640  REM  THE CONCENTRATION TERM IS CALCD AND COMPARED WITH K
00650  PRINT "THE CONCENTRATION TERM THIS TIME IS ";Q
00660  PRINT "IT IS SOMEWHAT ";D$;" THAN THE KEQ ";A
00670  PRINT "HENCE WE NEED A VALUE OF THE CONCENTRATION OF ";
00680  PRINT S$(3);" WHICH IS ";E$
00690  PRINT "WHAT IS YOUR GUESS?"
00700  GOSUB 1150
00710  GO TO 450
00720   PRINT "HENCE; YOU GUESS THAT EQUILIBRIUM OCCURS WHEN:"
00730  PRINT "(";S$(3);")=";X;" MOLES/L"
00740  PRINT "(";S$(4);")=";W;" MOLES/L"
00750  PRINT "(";S$(1);")=";Y;" MOLES/L"
00760  PRINT "(";S$(2);")=";Z;" MOLES/L"
00770  PRINT "(";S$(3);")";N(3);"(";S$(4);")";N(4)
00780 PRINT "--------------------------------"
00790  PRINT "(";S$(1);")";N(1);"(";S$(2);")";N(2)
00800  PRINT "  IS"
00810  PRINT "(";X↑N(3);")(";W↑N(4);")/(";Y↑N(1);")(";Z↑N(2);")=";Q
00820  GOSUB 1150
00830  PRINT "GUESS AGAIN FOR THE EQUILIBRIUM VALUE OF (";S$(3);")."
00840  GO TO 450
00850   PRINT "THIS GUESS IS CLOSE ENOUGH."
00860  PRINT "THE EXACT VALUES ARE:"
00870  LET X1=X
00880  LET Q1=Q
00890  LET X=1.02*X1
00900   GOSUB 1100
00910  IF Q1=Q THEN 970
00920  LET X2=X+(X1-X)/(Q1-Q)*(A-Q)
00930   LET X1=X
00940  LET X=X2
00950  LET Q1=Q
00960  IF X1=X THEN 900
00970   PRINT "  (";S$(3);")   =";X;" MOLES/LITER"
00980 LET W=N(4)/N(3)*X
00990 PRINT "  (";S$(4);")   =";W;" MOLES/LITER")
01000  LET Y=M1-N(1)/N(3)*X
```

```
01010  PRINT "  (";S$(1);")    =";Y;" MOLES/LITER"
01020  LET Z=M2-N(2)/N(3)*X
01030  PRINT "  (";S$(2);")    =";Z;" MOLES/LITER"
01040  STOP
01050   PRINT "FROM WHAT YOU HAVE ALREADY DONE "
01060  PRINT "YOU KNOW THAT THE CONCENTRATION OF    ";S$(3)
01070  PRINT "IS BETWEEN    ";C;" MOLES/L AND  ";D;" MOLES/L"
01080  PRINT "GUESS A VALUE BETWEEN THESE KNOWN LIMITS."
01090   GO TO 450
01100  LET W=N(4)/N(3)*X
01110  LET Y=M1-N(1)/N(3)*X
01120  LET Z=M2-N(2)/N(3)*X
01130  LET Q=X↑N(3)*W↑N(4)/Y↑N(1)/Z↑N(2)
01140  RETURN
01150  IF B=D THEN 1180
01160  LET D=X
01170  RETURN
01180   LET C=X
01190  RETURN
01200  REM  LIST OF EXAMPLES
01210 PRINT "4 HCL   +   O2   =   2 CL2   +   2 H2O"
01220 PRINT "4 NH3   +   5 O2   =   4 NO   +   6 H2O"
01230 PRINT "4 NH3   +   3 O2   =   2 N2   +   6 H2O"
01240 PRINT "CO   +   H2O   =   CO2   +   H2"
01250 PRINT "CH4   +   CL2   =   CH3CL   +   HCL"
01260 PRINT "2 NO   +   2 H2   =   N2   +   2 H2O"
01270 PRINT "CO   +   NO2   =   CO2   +   NO"
01280 PRINT "SO2   +   NO2   =   SO3   +   NO"
01290  RETURN
01300  END
END OF DATA
```

```
00010  REM EQUIZ  THIS IS A QUIZ GENERATING PROGRAM FOR EQUIL CALCNS
00020  REM  WRITTEN BY CYNTHIA JAMESON UNIV OF ILLINOIS CHICAGO CIRCLE
00030  REM  BOX 4348 CHICAGO 60680
00040  FOR UNIT 3 OF EQUILIBRIUM MODULE  IIT  AUG 1974
00050  REM  CAUTION: NOT ALL VERSIONS OF BASIC ALLOW STRING ARRAYS
00060  REM  M=0 FOR QUIZ PRINTING  M#0 FOR ANSWERS ONLY
00070   DIM N2(9),N1(3),S$(3),C(3),R$(10,3),K(10),T(10),C1(10,3)
00080   DATA "PCL3","CL2","PCL5"
00090  DATA "SO2","CL2","SO2CL2","C2H4","HBR","C2H5BR","CO","CL2","COCL2"
00100  DATA "C2H4","H2","C2H6","H2","I2","HI","I2","CL2","ICL"
00110  DATA "CO2","CF4","COF2","BR2","CL2","BRCL","N2","O2","NO"
00120   DATA 1,1,1,1,1,1,1,1,1,1,1,1,1,1,1
00130  DATA 1,1,2,1,1,2,1,1,2,1,1,2,1,1,2
00140  DATA 240,1E-3,1E-3,3.83E9,1480,625,2E5,.025,8.17E2,.10
00150  DATA 423,400,400,373,900,523,298,1273,573,2273
00160  FOR I=1 TO 10
00170  FOR J=1 TO 3
00180  READ R$(I,J)
00190  NEXT J
00200  NEXT I
00210  FOR I=1 TO 10
00220  FOR J=1 TO 3
00230  READ C1(I,J)
00240  NEXT J
00250  NEXT I
00260  FOR I=1 TO 10
00270  READ K(I)
00280  NEXT I
00290  FOR I=1 TO 10
00300  READ T(I)
00310  NEXT I
00320  M=1
00330   INPUT L
00340  IF L#0 THEN 380
00350  L=TIME(0)
00360   PRINT "QUIZ ";L
00370  M=0
00380  A=RND(-L)
00390   FOR L=1 TO 9
00400  N2(L)=L
00410  NEXT L
00420  GOSUB 2750
00430  FOR L=1 TO 9
00440  F=RND(0)+.001
00450  IF F<.05 THEN 440
00460  N=INT(10*RND(0))
00470   FOR J=1 TO 3
00480   S$(J)=R$(N,J)
00490   N1(J)=C1(N,J)
00500   NEXT J
```

```
00510   T0=T(N)
00520  K1=K(N)
00530  IF N2(L)=1 THEN 900
00540  IF N2(L)=2 THEN 760
00550  IF N2(L)=3 THEN 620
00560  IF N2(L)=4 THEN 1030
00570  IF N2(L)=5 THEN 1180
00580  IF N2(L)=6 THEN 1530
00590  IF N2(L)=7 THEN 1340
00600  IF N2(L)=8 THEN 1690
00610  IF N2(L)=9 THEN 1930
00620   IF K1 < 1.0 THEN 460
00630  M3=F*5
00640  D=M3
00650  M2=M1=0
00660  V=10
00670  A=M3
00680  GOSUB 2310
00690  A=(A-V*C(3))/A/N1(3)
00700  IF M#0 THEN 2180
00710 PRINT L;"."
00720 GOSUB 2710
00730  PRINT "FIND THE DEGREE OF DISSOCIATION OF ";D;" MOLES OF "
00740   PRINT S$(3);"IN A 10-LITER FLASK."
00750 GO TO 2190
00760   M3= F*5
00770  M1=M2=0
00780  V=10
00790  A=M3
00800  IF K1 < 1.0 THEN 460
00810  GOSUB 2310
00820  A=(A-V*C(3))/A/N1(3)
00830  IF M#0 THEN 2180
00840  PRINT L;".  WHEN THE SYSTEM"
00850 GOSUB 2240
00860 PRINT "IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:"
00870 GOSUB 2200
00880  PRINT "WHAT IS THE DEGREE OF DISSOCIATION OF ";S$(3);" ?"
00890 GO TO 2190
00900   M3=F*5
00910  M1=M2=0
00920  V=10
00930  GOSUB 2310
00940  A=K(N)
00950  IF M#0 THEN 2180
00960  PRINT L,".  AT EQUILIBRIUM, "
00970  PRINT " THE CONCENTRATIONS OF THE GASES IN THE REACTION"
00980  GOSUB 2240
00990  PRINT "ARE"
01000   GOSUB 2200
```

```
01010  PRINT "CALCULATE THE EQUILIBRIUM CONSTANT."
01020 GO TO 2190
01030   M3=F*5
01040  D=M3
01050  M1=M2=0
01060 V=.5 + 10*RND(0)
01070  T1=T0-273
01080  GOSUB 2310
01090  PRINT L;"."
01100  IF M=0 THEN 1130
01110  GOSUB 2200
01120  GO TO 2190
01130  PRINT D;" MOLES OF ";S$(3);" IS PLACED IN A ";V;" LITER"
01140 PRINT "FLASK AT ";T1;" DEG C.  WHEN THE CONTENTS HAVE COME TO"
01150  PRINT "EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
01160   GOSUB 2710
01170 GO TO 2190
01180   M3=0
01190  M1=F*5
01200  M2=5*RND(0)+.01
01210  V=.5 + 10*RND(0)
01220 T1=T0-273
01230  D=M1
01240  D1=M2
01250  A=C(3)*V
01260  IF M#0 THEN 2180
01270 PRINT L;".  IF ";D;" MOLE OF ";
01280 PRINT S$(1);" GAS AND ";D1;" MOLE OF ";S$(2)
01290 PRINT "GAS ARE PLACED IN A ";
01300 PRINT V;" LITER TANK AT ";T1;" DEG C;"
01310  PRINT "HOW MANY MOLES OF ";S$(3);" WILL BE PRESENT AT EQUILIBRIUM?"
01320 GOSUB 2710
01330   GO TO 2190
01340   M1=F*5
01350   M2=5*RND(0)+.01
01360  M3=5*RND(0)+.01
01370  V=5*RND(0)+.5
01380 T1=T0-273
01390  D=M1
01400  D1=M2
01410  D2=M3
01420  GOSUB 2310
01430  PRINT L;"."
01440  IF M=0 THEN 1470
01450  GOSUB 2200
01460  GO TO 2190
01470 GOSUB 2710
01480 PRINT D;" MOLES OF ";S$(1);" ;";D1;" MOLES OF ";S$(2)
01490 PRINT "AND ";D2;" MOLES OF ";S$(3);" GAS ARE INTRODUCED"
01500   PRINT "INTO AN EVACUATED ";V;" LITER FLASK AT ";T1;" DEG C."
```

```
01510 PRINT "FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES."
01520 GO TO 2190
01530   M1= 5*F
01540  M2=M1
01550  A=M1
01560  M3=0
01570  V=5*RND(0)+.5
01580 T1=T0-273
01590  D=M1
01600  A=V*(C(1)+C(2)+C(3))/2/A
01610  IF M#0 THEN 2180
01620 PRINT L;"."
01630   GOSUB 2710
01640 PRINT M1;" MOLE EACH OF ";S$(1);" AND ";S$(2);" GASES"
01650   PRINT "ARE PLACED IN A ";V;" LITER FLASK AT ";T1;" DEG C."
01660 PRINT "FIND THE RATIO OF THE TOTAL PRESSURE AT EQUILIBRIUM TO THE"
01670   PRINT "ORIGINAL TOTAL PRESSURE."
01680   GO TO 2190
01690   M3=F*5
01700  M1=M2=0
01710 P1=.1+5*RND(0)
01720  T1=T0-273
01730 V=5*RND(0)+.5
01740  GOSUB 2310
01750  IF M=0 THEN 1850
01760  M1=M1*V+P1
01770  M3=M3*V
01780  M2=M2*V
01790  M1=M1+M3*N1(1)/N1(3)
01800  M2=M2+M3*N1(2)/N1(3)
01810  M3=0
01820  GOSUB 2310
01830  A=C(3)
01840  GO TO 2180
01850 PRINT L;".  THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES "
01860  PRINT "IN THE REACTION:"
01870   GOSUB 2240
01880 PRINT "IN A ";V;" LITER CONTAINER AT ";T1;" DEG C ARE:"
01890 GOSUB 2200
01900  PRINT "IF ";P1;" MOLES OF ";S$(1);" IS THEN INTRODUCED;"
01910   PRINT "FIND THE NEW EQUILIBRIUM CONCENTRATION OF ";S$(3)
01920   GO TO 2190
01930   M3=F*5
01940   P1= .1 + 9*RND(0)
01950  V=10
01960  M1=M2=0
01970  P2 = 1+5*RND(0)
01980  GOSUB 2310
01990  IF M=0 THEN 2090
02000  M3=M3*V
```

```
02010  M2=M2*V
02020  M1=M1+M3*N1(1)/N1(3)
02030 M2=M2+M3*N1(2)/N1(3)
02040  M3=0
02050  V=V*P1/P2
02060  GOSUB 2310
02070  A=C(3)
02080  GO TO 2180
02090 PRINT L;".  THE FOLLOWING SYSTEM  IS AT EQUILIBRIUM:"
02100 GOSUB 2240
02110 PRINT "AT A TOTAL PRESSURE OF ";P1;" ATM"
02120 PRINT "THE EQUILIBRIUM CONCENTRATIONS ARE:"
02130   GOSUB 2200
02140 PRINT "IF THE PRESSURE IS CHANGED TO ";P2;" ATM"
02150 PRINT "AT CONSTANT TEMPERATURE; WHAT WILL THE "
02160 PRINT "NEW CONCENTRATION OF ";S$(3);" BE EQUAL TO?"
02170 GO TO 2190
02180   PRINT L;".";A
02190    NEXT L
02195  GO TO 2820
02200    PRINT "(";S$(1);") = ";C(1);" M"
02210   PRINT "(";S$(2);") = ";C(2);" M"
02220   PRINT "(";S$(3);") = ";C(3);" M"
02230  RETURN
02240  PRINT
02250   PRINT "   ";S$(1);"  +  ";S$(2);" === ";
02260  IF N>5 THEN 2290
02270  PRINT S$(3)
02280  RETURN
02290   PRINT N1(3);S$(3)
02300  RETURN
02310  M1=M1/V
02320  M2=M2/V
02330  M3=M3/V
02340  IF K1>1.0 THEN 2390
02350  M1=M1+M3/N1(3)
02360  M2=M2+M3/N1(3)
02370 M3=0
02380 X=(M1*M2*K1)↑(1/N1(3))/N1(3)
02390   IF K1<1.0 THEN 2540
02400  IF M1<M2 THEN 2450
02410  M3=M3+M2*N1(3)
02420  M1=M1-M2
02430  M2=0
02440 X=-M3↑N1(3)/K1/M1
02450   IF M2<M1 THEN 2500
02460  M3=M3+M1*N1(3)
02470  M2=M2-M1
02480  M1=0
02490 X=-M3↑N1(3)/K1/M2
02500   IF M1#M2 THEN 2540
```

```
02510  M3=M3+M1*N1(3)
02520  M1=M2=0
02530 X=-SQR(M3↑N1(3)/K1)
02540    X1=X
02550 Q1=K1
02560 X=1.02*X1
02570     C(1)=M1-N1(1)*X
02580    C(2)=M2-N1(2)*X
02590    C(3)=M3+N1(3)*X
02600 IF C(1) <=0 OR C(1) > 10 THEN 2820
02610 IF C(2) <=0 OR C(2) > 10 THEN 2820
02620 IF C(3) <=0 OR C(3) > 10 THEN 2820
02630    K2=C(3)↑N1(3)/C(1)↑N1(1)/C(2)↑N1(2)
02640    IF Q1=K2 THEN 2700
02650    X2=X+(X1-X)*(K1-K2)/(Q1-K2)
02660    X1=X
02670    X=X2
02680    Q1=K2
02690    IF X1#X THEN 2570
02700    RETURN
02710   PRINT "FOR THE EQUILIBRIUM:"
02720   GOSUB 2240
02730 PRINT "THE EQUILIBRIUM CONSTANT IS :  K = ";K1;" AT ";T0;" DEG K ."
02740   RETURN
02750   FOR J=1 TO 9 STEP 1
02760   I=INT(RND(0)*J)
02770 S=N2(I)
02780 N2(I)=N2(J)
02790 N2(J)=S
02800   NEXT J
02810   RETURN
02820   END
END OF DATA
```

Unit Test on Equilibrium Calculations time=20 min

TEST 1

1. FOR THE EQUILIBRIUM:

$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$

THE EQUILIBRIUM CONSTANT IS : K = 2.500E-02 AT 1273 DEG K .
0.495 MOLES OF CO_2 ,2.728 MOLES OF CF_4
AND 1.712 MOLES OF COF_2 GAS ARE INTRODUCED
INTO AN EVACUATED 1.10 LITER FLASK AT 1000 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

2. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$

IN A 2.55 LITER CONTAINER AT 25 DEG C ARE:
(I_2) = 3.21E-03 M
(Cl_2) = 3.21E-03 M
(ICl) = 1.43E+00 M
IF 0.26 MOLES OF I_2 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF ICl.

3. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$

ARE:
(SO_2) = 3.18E-01 M
(Cl_2) = 3.18E-01 M
(SO_2Cl_2) = 1.01E-04 M
CALCULATE THE EQUILIBRIUM CONSTANT.

4. IF 1.915 MOLE OF C_2H_4 GAS AND 1.207 MOLE OF HBr
GAS ARE PLACED IN A 0.40 LITER TANK AT 127 DEG C,
HOW MANY MOLES OF C_2H_5Br WILL BE PRESENT
AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-03 AT 400 DEG K .

Unit Test on Equilibrium Calculations time=20 min

TEST 2

1. FOR THE EQUILIBRIUM:

$CO + Cl_2 \equiv\equiv\equiv COCl_2$

THE EQUILIBRIUM CONSTANT IS : K = 3.830E+09 AT 373 DEG K .
4.585 MOLES OF CO ,1.817 MOLES OF Cl_2
AND 4.787 MOLES OF $COCl_2$ GAS ARE INTRODUCED
INTO AN EVACUATED 2.20 LITER FLASK AT 100 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

2. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$N_2 + O_2 \equiv\equiv\equiv 2\ NO$

ARE:
(N_2) = 1.46E-01 M
(O_2) = 1.46E-01 M
(NO) = 4.62E-02 M
CALCULATE THE EQUILIBRIUM CONSTANT.

3. IF 4.460 MOLE OF PCl_3 GAS AND 0.058 MOLE OF Cl_2
GAS ARE PLACED IN A 5.50 LITER TANK AT 150 DEG C,
HOW MANY MOLES OF PCl_5 WILL BE PRESENT
AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+02 AT 423 DEG K .

4. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$

AT A TOTAL PRESSURE OF 0.76 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(PCl_3) = 1.06E-01 M
(Cl_2) = 1.06E-01 M
(PCl_5) = 2.70E+00 M
IF THE PRESSURE IS CHANGED TO 2.75 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF PCl_5 BE EQUAL TO?

Unit Test on Equilibrium Calculations time=20 min

TEST 3

1.

FOR THE EQUILIBRIUM:

$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .
2.925 MOLES OF Br_2 ,0.343 MOLES OF Cl_2
AND 3.143 MOLES OF BrCl GAS ARE INTRODUCED
INTO AN EVACUATED 5.45 LITER FLASK AT 300 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

2. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$

IN A 1.80 LITER CONTAINER AT 127 DEG C ARE:
(SO_2) = 2.55E+00 M
(Cl_2) = 2.55E+00 M
(SO_2Cl_2) = 6.53E-03 M
IF 3.81 MOLES OF SO_2 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF SO_2Cl_2.

3. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$CO + Cl_2 \equiv\equiv\equiv COCl_2$

ARE:
(CO) = 9.33E-06 M
(Cl_2) = 9.33E-06 M
$(COCl_2)$ = 3.33E-01 M
CALCULATE THE EQUILIBRIUM CONSTANT.

4. IF 0.965 MOLE OF N_2 GAS AND 0.147 MOLE OF O_2
GAS ARE PLACED IN A 8.50 LITER TANK AT 2000 DEG C,
HOW MANY MOLES OF NO WILL BE PRESENT
AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$N_2 + O_2 \equiv\equiv\equiv 2\ NO$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-01 AT 2273 DEG K .

Unit Test on Equilibrium Calculations time=20 min

TEST 4

1. FOR THE EQUILIBRIUM:

$Br_2 + Cl_2 \rightleftharpoons 2\ BrCl$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .
4.340 MOLES OF Br_2 ,0.407 MOLES OF Cl_2
AND 4.537 MOLES OF BrCl GAS ARE INTRODUCED
INTO AN EVACUATED 4.50 LITER FLASK AT 300 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

2. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$H_2 + I_2 \rightleftharpoons 2\ HI$

AT A TOTAL PRESSURE OF 0.96 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(H_2) = 2.43E-02 M
(I_2) = 2.43E-02 M
(HI) = 6.07E-01 M
IF THE PRESSURE IS CHANGED TO 1.75 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF HI BE EQUAL TO?

3. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$CO_2 + CF_4 \rightleftharpoons 2\ COF_2$

ARE:
(CO_2) = 1.64E-01 M
(CF_4) = 1.64E-01 M
(COF_2) = 2.59E-02 M
CALCULATE THE EQUILIBRIUM CONSTANT.

4. 2.740 MOLES OF PCl_5 IS PLACED IN A 0.70 LITER
FLASK AT 150 DEG C. WHEN THE CONTENTS HAVE COME TO
EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
FOR THE EQUILIBRIUM:

$PCl_3 + Cl_2 \rightleftharpoons PCl_5$

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+02 AT 423 DEG K .

Unit Test on Equilibrium Calculations time=20 min

TEST 5

1. WHEN THE SYSTEM

$$H_2 + I_2 \equiv\equiv\equiv 2\ HI$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(H_2) = 8.41E-03 M
(I_2) = 8.41E-03 M
(HI) = 2.10E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF HI ?

2. FOR THE EQUILIBRIUM:

$$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-03 AT 400 DEG K .
2.510 MOLES OF C_2H_4 ,1.103 MOLES OF HBr
AND 1.532 MOLES OF C_2H_5Br GAS ARE INTRODUCED
INTO AN EVACUATED 1.30 LITER FLASK AT 127 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

3. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$$

IN A 1.45 LITER CONTAINER AT 127 DEG C ARE:
(C_2H_4) = 8.89E-01 M
(HBr) = 8.89E-01 M
(C_2H_5Br) = 7.90E-04 M
IF 0.66 MOLES OF C_2H_4 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF C_2H_5Br.

4. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$$

ARE:
(CO_2) = 1.71E-02 M
(CF_4) = 1.71E-02 M
(COF_2) = 2.71E-03 M
CALCULATE THE EQUILIBRIUM CONSTANT.

Unit Test on Equilibrium Calculations time=20 min

TEST 6

1. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$

AT A TOTAL PRESSURE OF 1.01 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(CO_2) = 6.37E-02 M
(CF_4) = 6.37E-02 M
(COF_2) = 1.01E-02 M
IF THE PRESSURE IS CHANGED TO 4.30 ATM AT CONSTANT TEMPERATURE, WHAT WILL THE NEW CONCENTRATION OF COF_2 BE EQUAL TO?

2. WHEN THE SYSTEM

$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(PCl_3) = 2.78E-02 M
(Cl_2) = 2.78E-02 M
(PCl_5) = 1.86E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF PCl_5 ?

3. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$

ARE:
(C_2H_4) = 3.85E-02 M
(HBr) = 3.85E-02 M
(C_2H_5Br) = 1.48E-06 M
CALCULATE THE EQUILIBRIUM CONSTANT.

4. FOR THE EQUILIBRIUM:

$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-03 AT 400 DEG K .
3.040 MOLES OF SO_2 ,4.383 MOLES OF Cl_2
AND 3.112 MOLES OF SO_2Cl_2 GAS ARE INTRODUCED
INTO AN EVACUATED 2.65 LITER FLASK AT 127 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

Unit Test on Equilibrium Calculations time=20 min

TEST 7

1.

FOR THE EQUILIBRIUM:

$N_2 + O_2 \equiv\equiv\equiv 2\ NO$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-01 AT 2273 DEG K .
3.515 MOLES OF N_2 ,4.487 MOLES OF O_2
AND 2.308 MOLES OF NO GAS ARE INTRODUCED
INTO AN EVACUATED 5.25 LITER FLASK AT 2000 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

2. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$

IN A 1.30 LITER CONTAINER AT 1000 DEG C ARE:
(CO_2) = 7.95E-01 M
(CF_4) = 7.95E-01 M
(COF_2) = 1.26E-01 M
IF 1.06 MOLES OF CO_2 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF COF_2.

3. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$N_2 + O_2 \equiv\equiv\equiv 2\ NO$

ARE:
(N_2) = 1.82E-01 M
(O_2) = 1.82E-01 M
(NO) = 5.76E-02 M
CALCULATE THE EQUILIBRIUM CONSTANT.

4. IF 1.375 MOLE OF CO GAS AND 1.482 MOLE OF Cl_2
GAS ARE PLACED IN A 8.80 LITER TANK AT 100 DEG C,
HOW MANY MOLES OF $COCl_2$ WILL BE PRESENT
AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$CO + Cl_2 \equiv\equiv\equiv COCl_2$

THE EQUILIBRIUM CONSTANT IS : K = 3.830E+09 AT 373 DEG K .

Unit Test on Equilibrium Calculations time=20 min

TEST 8

1. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$H_2 + I_2 \equiv\equiv\equiv 2\ HI$$

ARE:
(H_2) = 1.00E-02 M
(I_2) = 1.00E-02 M
(HI) = 2.56E-01 M
CALCULATE THE EQUILIBRIUM CONSTANT.

2. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$$

AT A TOTAL PRESSURE OF 2.31 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(SO_2) = 9.74E-01 M
(Cl_2) = 9.74E-01 M
(SO_2Cl_2) = 9.48E-04 M
IF THE PRESSURE IS CHANGED TO 3.05 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF SO_2Cl_2 BE EQUAL TO?

3.

FOR THE EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .
2.270 MOLES OF I_2 ,2.582 MOLES OF Cl_2
AND 2.968 MOLES OF ICl GAS ARE INTRODUCED
INTO AN EVACUATED 2.15 LITER FLASK AT 25 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

4. WHEN THE SYSTEM

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(CO) = 8.58E-06 M
(Cl_2) = 8.58E-06 M
($COCl_2$) = 2.82E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF $COCl_2$?

Unit Test on Equilibrium Calculations time=20 min

TEST 9

1. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$$

AT A TOTAL PRESSURE OF 2.11 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(CO_2) = 2.41E-01 M
(CF_4) = 2.41E-01 M
(COF_2) = 3.82E-02 M
IF THE PRESSURE IS CHANGED TO 5.85 ATM AT CONSTANT TEMPERATURE, WHAT WILL THE NEW CONCENTRATION OF COF_2 BE EQUAL TO?

2. IF 2.100 MOLE OF C_2H_4 GAS AND 3.728 MOLE OF H_2 GAS ARE PLACED IN A 9.30 LITER TANK AT 627 DEG C, HOW MANY MOLES OF C_2H_6 WILL BE PRESENT AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

THE EQUILIBRIUM CONSTANT IS : K = 1.480E+03 AT 900 DEG K .

3. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$$

ARE:
(CO_2) = 1.51E-02 M
(CF_4) = 1.51E-02 M
(COF_2) = 2.38E-03 M
CALCULATE THE EQUILIBRIUM CONSTANT.

4.
FOR THE EQUILIBRIUM:

$$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$$

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+02 AT 423 DEG K .
1.230 MOLES OF PCl_3 ,0.362 MOLES OF Cl_2 AND 4.272 MOLES OF PCl_5 GAS ARE INTRODUCED INTO AN EVACUATED 0.70 LITER FLASK AT 150 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

Unit Test on Equilibrium Calculations time=20 min

TEST 10

1. FOR THE EQUILIBRIUM:

$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .
1.760 MOLES OF I_2 ,4.537 MOLES OF Cl_2
AND 1.207 MOLES OF ICl GAS ARE INTRODUCED
INTO AN EVACUATED 1.90 LITER FLASK AT 25 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

2. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$

ARE:
(C_2H_4) = 3.46E-01 M
(HBr) = 3.46E-01 M
(C_2H_5Br) = 1.20E-04 M
CALCULATE THE EQUILIBRIUM CONSTANT.

3. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$H_2 + I_2 \equiv\equiv\equiv 2\ HI$

IN A 1.30 LITER CONTAINER AT 250 DEG C ARE:
(H_2) = 1.27E-01 M
(I_2) = 1.27E-01 M
(HI) = 3.18E+00 M
IF 1.66 MOLES OF H[illegible]3 THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF HI.

4. 1.815 MOLES OF PCl_5 IS PLACED IN A 2.30 LITER
FLASK AT 150 DEG C. WHEN THE CONTENTS HAVE COME TO
EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES?
FOR THE EQUILIBRIUM:

$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+02 AT 423 DEG K .

Unit Test on Equilibrium Calculations time=20 min

TEST 11

1. 4.180 MOLES OF HI IS PLACED IN A 8.50 LITER FLASK AT 250 DEG C. WHEN THE CONTENTS HAVE COME TO EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES? FOR THE EQUILIBRIUM:

$$H_2 + I_2 \equiv\equiv 2\ HI$$

THE EQUILIBRIUM CONSTANT IS : K = 6.250E+02 AT 523 DEG K .

2. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$H_2 + I_2 \equiv\equiv 2\ HI$$

ARE:
(H_2) = 9.63E-03 M
(I_2) = 9.63E-03 M
(HI) = 2.41E-01 M
CALCULATE THE EQUILIBRIUM CONSTANT.

3. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$N_2 + O_2 \equiv\equiv 2\ NO$$

IN A 4.95 LITER CONTAINER AT 2000 DEG C ARE:
(N_2) = 2.75E-02 M
(O_2) = 2.75E-02 M
(NO) = 8.69E-03 M
IF 1.61 MOLES OF N_2 IS THEN INTRODUCED, FIND THE NEW EQUILIBRIUM CONCENTRATION OF NO.

4. FOR THE EQUILIBRIUM:

$$C_2H_4 + HBr \equiv\equiv C_2H_5Br$$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-03 AT 400 DEG K .
4.440 MOLES OF C_2H_4 ,3.777 MOLES OF HBr
AND 2.242 MOLES OF C_2H_5Br GAS ARE INTRODUCED
INTO AN EVACUATED 3.65 LITER FLASK AT 127 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

Unit Test on Equilibrium Calculations time=20 min

TEST 12

1. WHEN THE SYSTEM

$$Br_2 + Cl_2 \rightleftharpoons 2\ BrCl$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(Br_2) = 3.02E-03 M
(Cl_2) = 3.02E-03 M
(BrCl) = 8.64E-02 M
WHAT IS THE DEGREE OF DISSOCIATION OF BrCl ?

2. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$C_2H_4 + HBr \rightleftharpoons C_2H_5Br$$

ARE:
(C_2H_4) = 3.27E-01 M
(HBr) = 3.27E-01 M
(C_2H_5Br) = 1.07E-04 M
CALCULATE THE EQUILIBRIUM CONSTANT.

3. FOR THE EQUILIBRIUM:

$$N_2 + O_2 \rightleftharpoons 2\ NO$$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-01 AT 2273 DEG K .
0.660 MOLES OF N_2 ,3.952 MOLES OF O_2
AND 0.537 MOLES OF NO GAS ARE INTRODUCED
INTO AN EVACUATED 0.75 LITER FLASK AT 2000 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

4. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$C_2H_4 + H_2 \rightleftharpoons C_2H_6$$

IN A 3.00 LITER CONTAINER AT 627 DEG C ARE:
(C_2H_4) = 1.50E-02 M
(H_2) = 1.50E-02 M
(C_2H_6) = 3.32E-01 M
IF 2.86 MOLES OF C_2H_4 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF C_2H_6.

Unit Test on Equilibrium Calculations time=20 min

TEST 13

1. FOR THE EQUILIBRIUM:

$CO + Cl_2 \equiv\equiv\equiv COCl_2$

THE EQUILIBRIUM CONSTANT IS : K = 3.830E+09 AT 373 DEG K .
3.540 MOLES OF CO ,3.877 MOLES OF Cl_2
AND 1.487 MOLES OF $COCl_2$ GAS ARE INTRODUCED
INTO AN EVACUATED 2.30 LITER FLASK AT 100 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

2. WHEN THE SYSTEM

$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(PCl_3) = 3.60E-02 M
(Cl_2) = 3.60E-02 M
(PCl_5) = 3.11E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF PCl_5 ?

3. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$H_2 + I_2 \equiv\equiv\equiv 2\ HI$

ARE:
(H_2) = 1.36E-02 M
(I_2) = 1.36E-02 M
(HI) = 3.41E-01 M
CALCULATE THE EQUILIBRIUM CONSTANT.

4. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$

IN A 3.65 LITER CONTAINER AT 127 DEG C ARE:
(SO_2) = 7.12E-02 M
(Cl_2) = 7.12E-02 M
(SO_2Cl_2) = 5.07E-06 M
IF 4.76 MOLES OF SO_2 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF SO_2Cl_2.

Unit Test on Equilibrium Calculations time=20 min

TEST 14

1. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$N_2 + O_2 \text{ === } 2\ NO$$

AT A TOTAL PRESSURE OF 3.41 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(N_2) = 2.51E-01 M
(O_2) = 2.51E-01 M
(NO) = 7.95E-02 M
IF THE PRESSURE IS CHANGED TO 1.80 ATM AT CONSTANT TEMPERATURE, WHAT WILL THE NEW CONCENTRATION OF NO BE EQUAL TO?

2. IF 2.815 MOLE OF Br_2 GAS AND 3.622 MOLE OF Cl_2 GAS ARE PLACED IN A 1.10 LITER TANK AT 300 DEG C, HOW MANY MOLES OF BrCl WILL BE PRESENT AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$Br_2 + Cl_2 \text{ === } 2\ BrCl$$

THE EQUILIBRIUM CONSTANT IS : K = 8.170E+02 AT 573 DEG K .

3. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$SO_2 + Cl_2 \text{ === } SO_2Cl_2$$

ARE:
(SO_2) = 7.15E-02 M
(Cl_2) = 7.15E-02 M
(SO_2Cl_2) = 5.11E-06 M
CALCULATE THE EQUILIBRIUM CONSTANT.

4. FOR THE EQUILIBRIUM:

$$PCl_3 + Cl_2 \text{ === } PCl_5$$

THE EQUILIBRIUM CONSTANT IS : K = 2.400E+02 AT 423 DEG K .
2.515 MOLES OF PCl_3 ,2.282 MOLES OF Cl_2 AND 0.402 MOLES OF PCl_5 GAS ARE INTRODUCED INTO AN EVACUATED 3.50 LITER FLASK AT 150 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

Unit Test on Equilibrium Calculations time=20 min

TEST 15

1.

FOR THE EQUILIBRIUM:

$$H_2 + I_2 \equiv\equiv\equiv 2\ HI$$

THE EQUILIBRIUM CONSTANT IS : K = 6.250E+02 AT 523 DEG K .
3.090 MOLES OF H_2 ,2.688 MOLES OF I_2
AND 4.383 MOLES OF HI GAS ARE INTRODUCED
INTO AN EVACUATED 4.25 LITER FLASK AT 250 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

2.

FOR THE EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 2.250 MOLES OF ICl
IN A 10-LITER FLASK.

3. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$$

ARE:
(SO_2) = 2.24E-01 M
(Cl_2) = 2.24E-01 M
(SO_2Cl_2) = 5.02E-05 M
CALCULATE THE EQUILIBRIUM CONSTANT.

4. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$C_2H_4 + H_2 \equiv\equiv\equiv C_2H_6$$

IN A 3.90 LITER CONTAINER AT 627 DEG C ARE:
(C_2H_4) = 2.36E-02 M
(H_2) = 2.36E-02 M
(C_2H_6) = 8.21E-01 M
IF 1.56 MOLES OF C_2H_4 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF C_2H_6.

Unit Test on Equilibrium Calculations time=20 min

TEST 16

1.

FOR THE EQUILIBRIUM:

$$H_2 + I_2 \equiv\equiv\equiv 2\ HI$$

THE EQUILIBRIUM CONSTANT IS : K = 6.250E+02 AT 523 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 4.485 MOLES OF HI
IN A 10-LITER FLASK.

2.

FOR THE EQUILIBRIUM:

$$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$$

THE EQUILIBRIUM CONSTANT IS : K = 2.500E-02 AT 1273 DEG K .
0.495 MOLES OF CO_2 ,1.438 MOLES OF CF_4
AND 0.417 MOLES OF COF_2 GAS ARE INTRODUCED
INTO AN EVACUATED 1.60 LITER FLASK AT 1000 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

3. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$$

AT A TOTAL PRESSURE OF 2.26 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(CO_2) = 1.69E-01 M
(CF_4) = 1.69E-01 M
(COF_2) = 2.66E-02 M
IF THE PRESSURE IS CHANGED TO 1.65 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF COF_2 BE EQUAL TO?

4. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$$

ARE:
(C_2H_4) = 1.99E-01 M
(HBr) = 1.99E-01 M
(C_2H_5Br) = 3.98E-05 M
CALCULATE THE EQUILIBRIUM CONSTANT.

Unit Test on Equilibrium Calculations time=20 min

TEST 17

1.

FOR THE EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .
1.265 MOLES OF I_2 ,0.212 MOLES OF Cl_2
AND 0.607 MOLES OF ICl GAS ARE INTRODUCED
INTO AN EVACUATED 1.85 LITER FLASK AT 25 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

2. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$$

ARE:
(C_2H_4) = 1.55E-01 M
(HBr) = 1.55E-01 M
(C_2H_5Br) = 2.42E-05 M
CALCULATE THE EQUILIBRIUM CONSTANT.

3.

FOR THE EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .
FIND THE DEGREE OF DISSOCIATION OF 3.105 MOLES OF ICl
IN A 10-LITER FLASK.

4. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$PCl_3 + Cl_2 \equiv\equiv\equiv PCl_5$$

IN A 4.00 LITER CONTAINER AT 150 DEG C ARE:
(PCl_3) = 5.59E-02 M
(Cl_2) = 5.59E-02 M
(PCl_5) = 7.49E-01 M
IF 2.96 MOLES OF PCl_3 IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF PCl_5.

Unit Test on Equilibrium Calculations time=20 min

TEST 18

1. THE EQUILIBRIUM CONCENTRATIONS OF THE SPECIES IN THE REACTION

$$CO + Cl_2 \equiv\equiv\equiv COCl_2$$

IN A 3.55 LITER CONTAINER AT 100 DEG C ARE:
$(CO) = 7.20E-06$ M
$(Cl_2) = 7.20E-06$ M
$(COCl_2) = 1.99E-01$ M
IF 4.66 MOLES OF CO IS THEN INTRODUCED,
FIND THE NEW EQUILIBRIUM CONCENTRATION OF $COCl_2$.

2. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

ARE:
$(I_2) = 3.68E-04$ M
$(Cl_2) = 3.68E-04$ M
$(ICl) = 1.65E-01$ M
CALCULATE THE EQUILIBRIUM CONSTANT.

3. IF 3.400 MOLE OF Br_2 GAS AND 3.997 MOLE OF Cl_2 GAS ARE PLACED IN A 1.30 LITER TANK AT 300 DEG C, HOW MANY MOLES OF BrCl WILL BE PRESENT AT EQUILIBRIUM?
FOR THE EQUILIBRIUM:

$$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$$

THE EQUILIBRIUM CONSTANT IS : $K = 8.170E+02$ AT 573 DEG K .

4.
FOR THE EQUILIBRIUM:

$$Br_2 + Cl_2 \equiv\equiv\equiv 2\ BrCl$$

THE EQUILIBRIUM CONSTANT IS : $K = 8.170E+02$ AT 573 DEG K .
4.955 MOLES OF Br_2 ,4.473 MOLES OF Cl_2
AND 3.502 MOLES OF BrCl GAS ARE INTRODUCED
INTO AN EVACUATED 1.50 LITER FLASK AT 300 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

Unit Test on Equilibrium Calculations time=20 min

TEST 19

1. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$

AT A TOTAL PRESSURE OF 2.21 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(SO_2) = 1.33E+00 M
(Cl_2) = 1.33E+00 M
(SO_2Cl_2) = 1.76E-03 M
IF THE PRESSURE IS CHANGED TO 3.40 ATM AT CONSTANT TEMPERATURE, WHAT WILL THE NEW CONCENTRATION OF SO_2Cl_2 BE EQUAL TO?

2. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$C_2H_4 + HBr \equiv\equiv\equiv C_2H_5Br$

ARE:
(C_2H_4) = 4.80E-01 M
(HBr) = 4.80E-01 M
(C_2H_5Br) = 2.31E-04 M
CALCULATE THE EQUILIBRIUM CONSTANT.

3. 3.465 MOLES OF ICl IS PLACED IN A 5.20 LITER FLASK AT 25 DEG C. WHEN THE CONTENTS HAVE COME TO EQUILIBRIUM, WHAT WILL BE THE CONCENTRATIONS OF ALL THE GASES? FOR THE EQUILIBRIUM:

$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .

4.

FOR THE EQUILIBRIUM:

$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$

THE EQUILIBRIUM CONSTANT IS : K = 1.000E-03 AT 400 DEG K .
4.015 MOLES OF SO_2 ,2.117 MOLES OF Cl_2
AND 1.067 MOLES OF SO_2Cl_2 GAS ARE INTRODUCED
INTO AN EVACUATED 2.30 LITER FLASK AT 127 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

Unit Test on Equilibrium Calculations time=20 min

TEST 20

1. AT EQUILIBRIUM, THE CONCENTRATIONS OF THE GASES IN THE REACTION

$$CO_2 + CF_4 \equiv\equiv\equiv 2\ COF_2$$

ARE:
(CO_2) = 2.30E-01 M
(CF_4) = 2.30E-01 M
(COF_2) = 3.68E-02 M
CALCULATE THE EQUILIBRIUM CONSTANT.

2. THE FOLLOWING SYSTEM IS AT EQUILIBRIUM:

$$SO_2 + Cl_2 \equiv\equiv\equiv SO_2Cl_2$$

AT A TOTAL PRESSURE OF 0.86 ATM THE EQUILIBRIUM CONCENTRATIONS ARE:
(SO_2) = 5.88E+00 M
(Cl_2) = 5.88E+00 M
(SO_2Cl_2) = 3.45E-02 M
IF THE PRESSURE IS CHANGED TO 1.30 ATM AT CONSTANT TEMPERATURE,
WHAT WILL THE NEW CONCENTRATION OF SO_2Cl_2 BE EQUAL TO?

3.

FOR THE EQUILIBRIUM:

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

THE EQUILIBRIUM CONSTANT IS : K = 2.000E+05 AT 298 DEG K .
1.405 MOLES OF I_2 ,1.667 MOLES OF Cl_2
AND 0.093 MOLES OF ICl GAS ARE INTRODUCED
INTO AN EVACUATED 1.30 LITER FLASK AT 25 DEG C.
FIND THE EQUILIBRIUM CONCENTRATIONS OF ALL THE GASES.

4. WHEN THE SYSTEM

$$I_2 + Cl_2 \equiv\equiv\equiv 2\ ICl$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:
(I_2) = 5.24E-04 M
(Cl_2) = 5.24E-04 M
(ICl) = 2.34E-01 M
WHAT IS THE DEGREE OF DISSOCIATION OF ICl ?

ANSWERS TO UNIT TESTS

Test 1

1. $[CO_2]$ = 1.08E+00 M
   $[CF_4]$ = 3.11E+00 M
   $[COF_2]$ = 2.90E-01 M
2. 1.44E+00 M
3. 1.00E-03
4. 2.22E-04

Test 2

1. $[CO]$ = 1.26E+00 M
   $[Cl_2]$ = 6.23E-10 M
   $[COCl_2]$ = 3.00E+00 M
2. 1.00E-01
3. 5.73E-02
4. 9.91E+00 M

Test 3

1. $[Br_2]$ = 4.75E-01 M
   $[Cl_2]$ = 1.26E-03 M
   [BrCl] = 7.00E-01 M
2. 1.19E-02 M
3. 3.83E+09
4. 9.56E-02

Test 4

1. $[Br_2]$ = 8.76E-01 M
   $[Cl_2]$ = 1.96E-03 M
   [BrCl] = 1.19E+00 M
2. 1.10E+00 M
3. 2.50E-02
4. $[PCl_3]$ = 1.26E-01 M
   $[Cl_2]$ = 1.26E-01 M
   $[PCl_5]$ = 3.79E+00 M

Test 5

1. 3.70E-02
2. $[C_2H_4]$ = 3.10E+00 M
   [HBr] = 2.02E+00 M
   $[C_2H_5Br]$ = 6.27E-03 M
3. 1.20E-03 M
4. 2.50E-02

Test 6

1. 4.28E-02 M
2. 1.30E-01
3. 1.00E-03
4. $[SO_2]$ = 2.32E+00 M
   $[Cl_2]$ = 2.82E+00 M
   $[SO_2Cl_2]$ = 6.53E-03 M

Test 7

1. $[N_2]$ = 7.56E-01 M
   $[O_2]$ = 9.41E-01 M
   [NO] = 2.67E-01 M
2. 1.75E-01 M
3. 1.00E-01
4. 1.37E+00

Test 8

1. 6.25E+02
2. 1.65E-03 M
3. $[I_2]$ = 4.19E-04 M
   $[Cl_2]$ = 1.46E-01 M
   [ICl] = 3.49E+00 M
4. 3.04E-05

Test 9	1.	1.06E-01 M	2. 2.09E+00 3. 2.30E-02 4. $[PCl_3]$ = 1.26E+00 M $[Cl_2]$ = 2.18E-02 M $[PCl_5]$ = 6.60E+00 M
Test 10	1.	$[I_2]$ = 2.12E-05 M $[Cl_2]$ = 1.46E+00 M [ICl] = 2.49E+00 M	2. 1.00E-03 3. 3.41E+00 M 4. $[PCl_3]$ = 5.53E-02 M $[Cl_2]$ = 5.53E-02 M $[PCl_5]$ = 7.34E-01 M
Test 11	1.	$[H_2]$ = 1.82E-02 M $[I_2]$ = 1.82E-02 M [HI] = 4.55E-01 M	2. 6.25E+02 3. 2.56E-02 M 4. $[C_2H_4]$ = 1.83E+00 M [HBr] = 1.65E+00 M $[C_2H_5Br]$ = 3.01E-03 M
Test 12	1.	3.27E-02	2. 1.00E-03 3. $[N_2]$ = 8.94E-01 M $[O_2]$ = 5.28E+00 M [NO] = 6.87E-01 M 4. 3.46E-01 M
Test 13	1.	[CO] = 3.89E-09 M $[Cl_2]$ = 1.47E-01 M $[COCl_2]$ = 2.19E+00 M	2. 1.04E-01 3. 6.25E+02 4. 9.78E-05 M
Test 14	1.	4.19E-02 M	2. 5.54E+00 3. 1.00E-03 4. $[PCl_3]$ = 9.78E-02 M $[Cl_2]$ = 3.13E-02 M $[PCl_5]$ = 7.36E-01 M
Test 15	1.	$[H_2]$ = 1.47E-01 M $[I_2]$ = 5.23E-02 M [HI] = 2.19E+00 M	2. 2.23E-03 3. 1.00E-03 4. 8.43E-01 M
Test 16	1.	3.70E-02	2. $[CO_2]$ = 3.91E-01 M $[CF_4]$ = 9.80E-01 M $[COF_2]$ = 9.78E-02 M 3. 1.94E-02 M 4. 1.00E-03

Test 17 1. $[I_2]$ = 5.69E-01 M
$[Cl_2]$ = 2.73E-06 M
[ICl] = 5.57E-01 M

2. 1.00E-03
3. 2.23E-03
4. 8.01E-01 M

Test 18 1. 1.99E-01 M

2. 2.00E+05
3. 6.64E+00
4. $[Br_2]$ = 4.83E-01 M
$[Cl_2]$ = 1.61E-01 M
[BrCl] = 7.98E+00 M

Test 19 1. 4.16E-03 M

2. 1.00E-03
3. $[I_2]$ = 1.48E-03 M
$[Cl_2]$ = 1.48E-03 M
[ICl] = 6.63E-01 M
4. $[SO_2]$ = 2.21E+00 M
$[Cl_2]$ = 1.38E+00 M
$[SO_2Cl_2]$ = 3.05E-03 M

Test 20 1. 2.50E-02

2. 7.80E-02 M
3. $[I_2]$ = 1.24E-04 M
$[Cl_2]$ = 2.02E-01 M
[ICl] = 2.23E+00 M
4. 2.23E-03